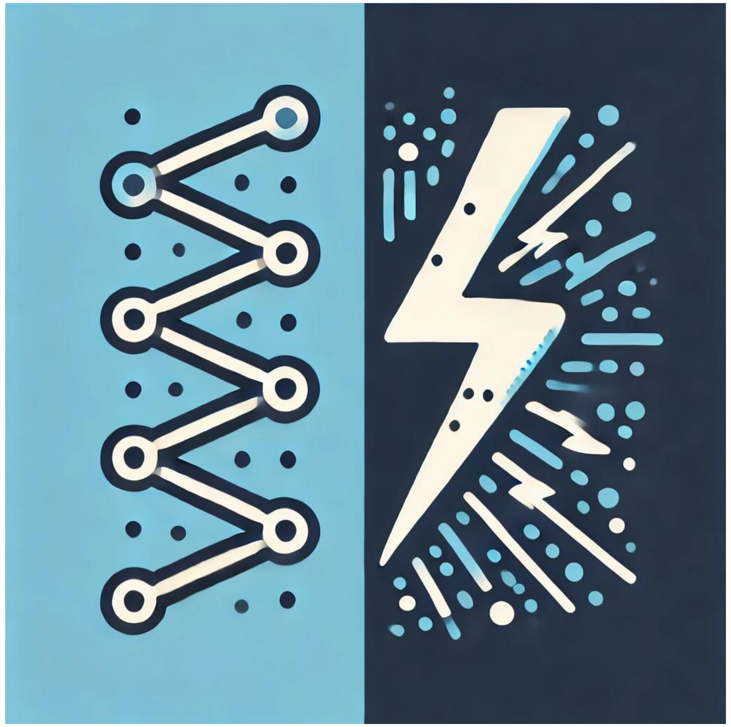
Empirical Software Engineering Research in the Age of LLMs

Christoph Treude

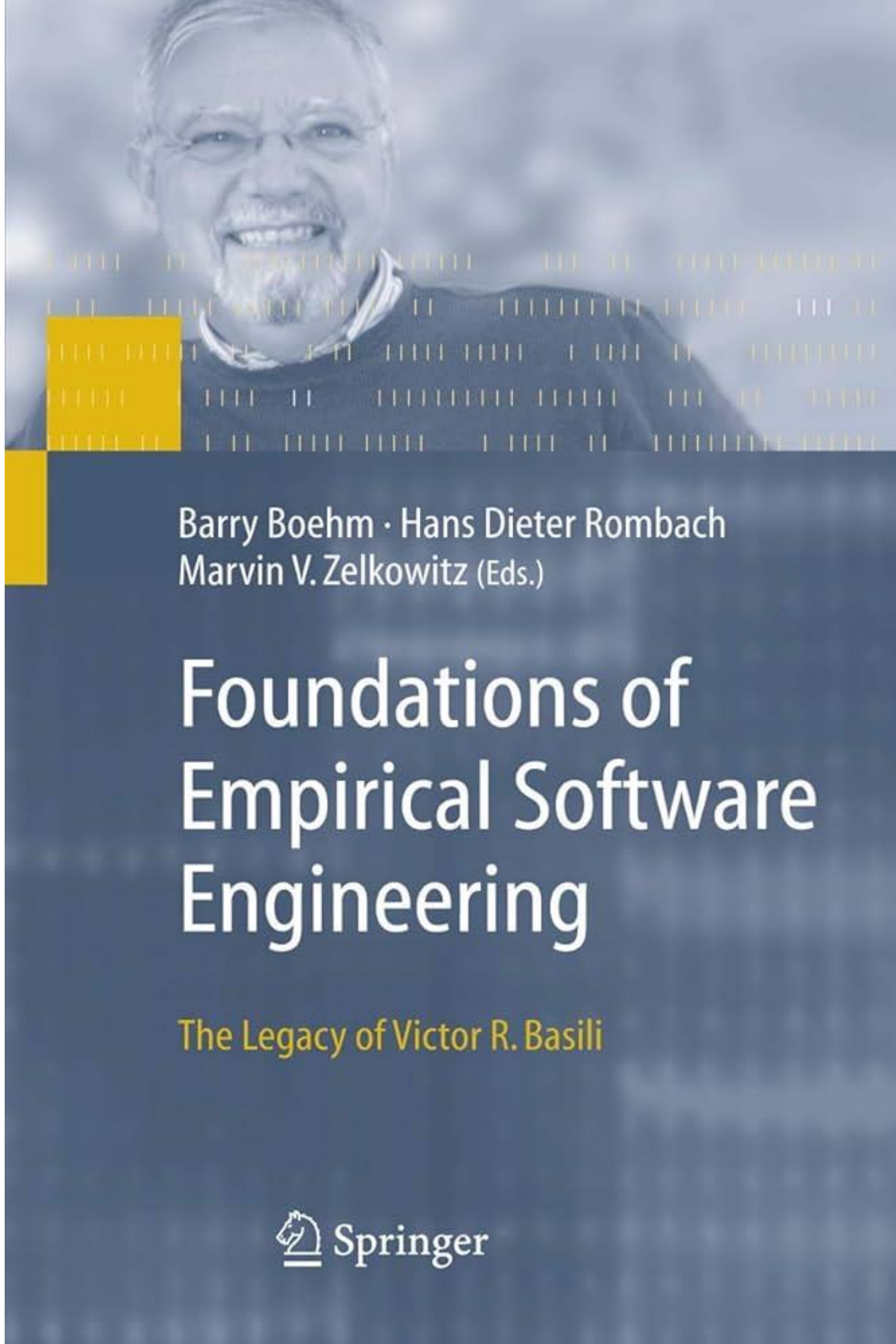


SINGAPORE MANAGEMENT UNIVERSITY

Empirical SE

“Empirical software engineering is the study of **software-related artifacts** for the characterization, understanding, evaluation, prediction, control, management, or improvement through qualitative or quantitative analysis.”

[Harrison and Basili]



Barry Boehm · Hans Dieter Rombach
Marvin V. Zelkowitz (Eds.)

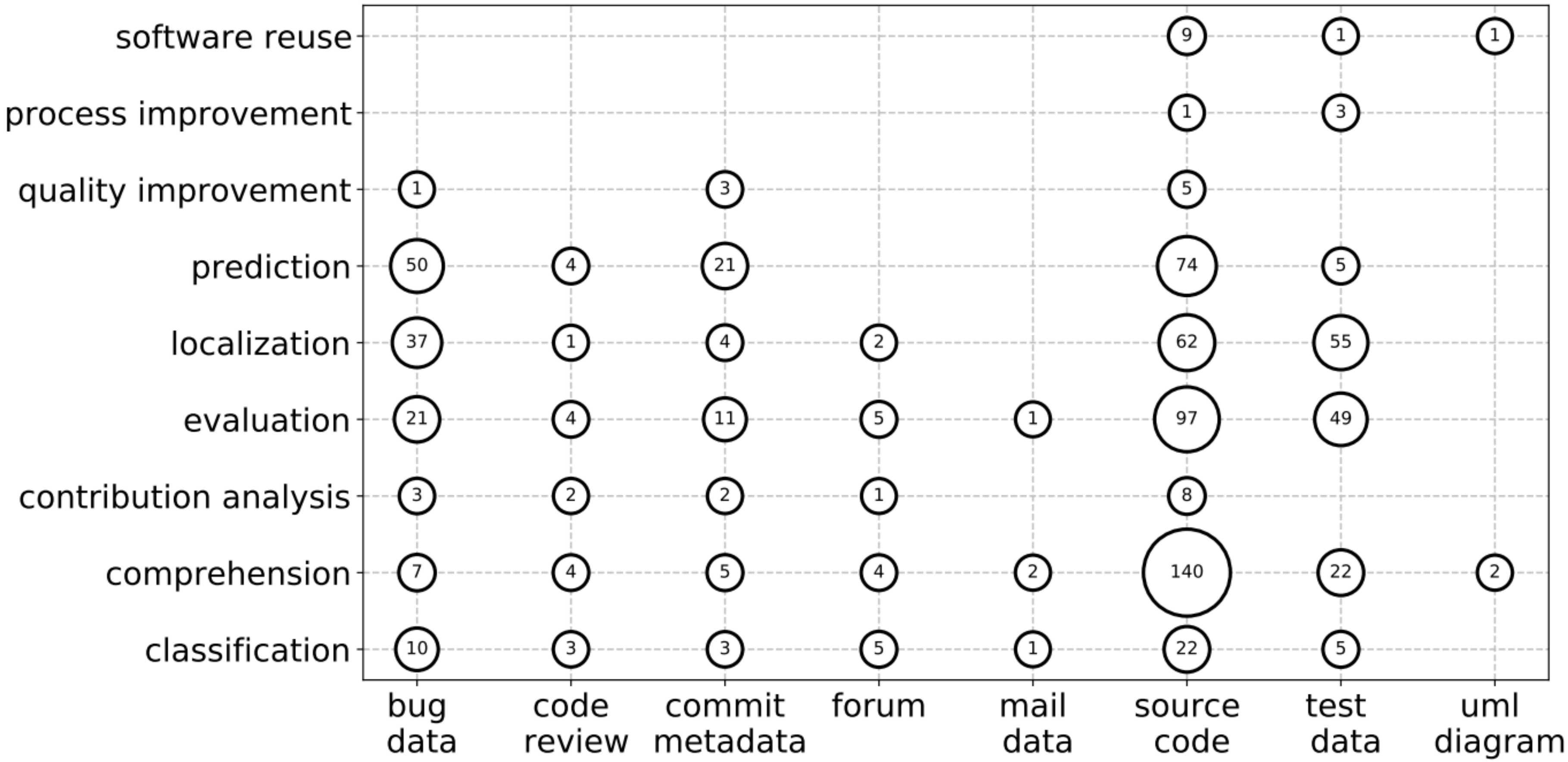
Foundations of Empirical Software Engineering

The Legacy of Victor R. Basili

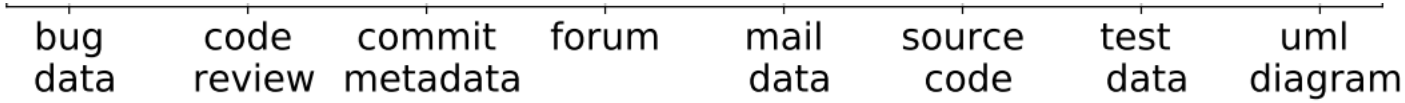
Springer

Software Artifact Mining

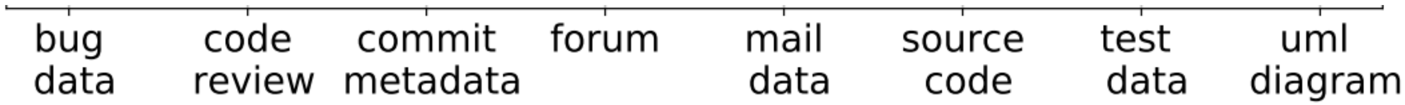
[Abou Khalil and Zacchiroli, ESEM 2022]



Software Artifact Mining



Software Artifact ~~Mining~~ Generation



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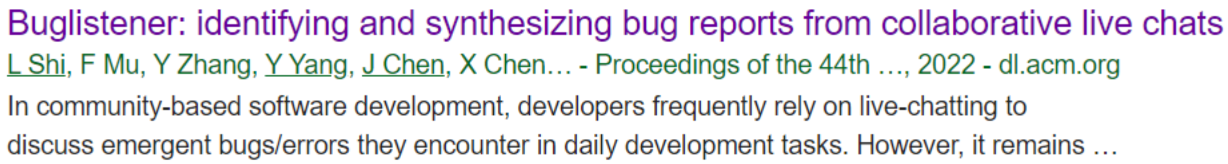
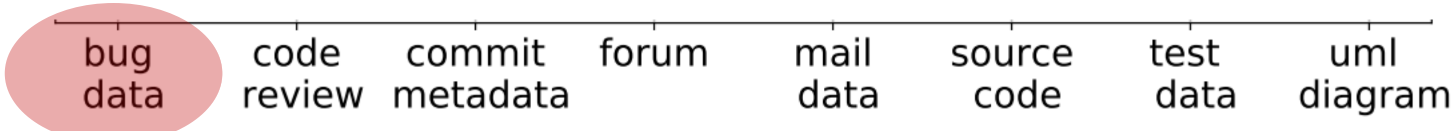


Buglistener: identifying and synthesizing bug reports from collaborative live chats

L Shi, F Mu, Y Zhang, Y Yang, J Chen, X Chen… - Proceedings of the 44th …, 2022 - dl.acm.org

In community-based software development, developers frequently rely on live-chatting to discuss emergent bugs/errors they encounter in daily development tasks. However, it remains …

[ICSE 2022]



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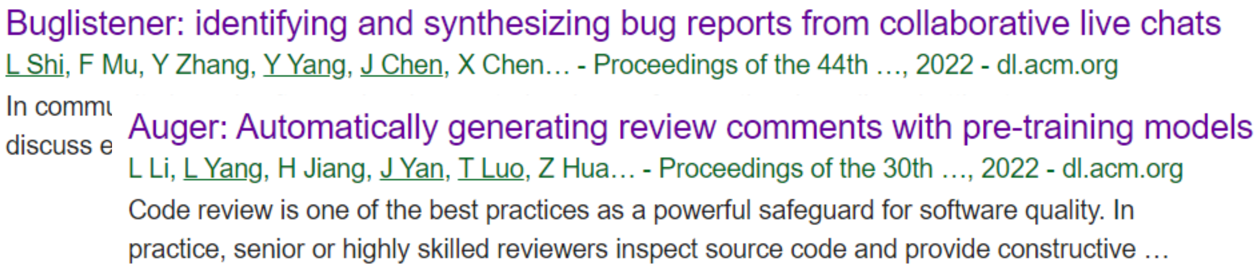

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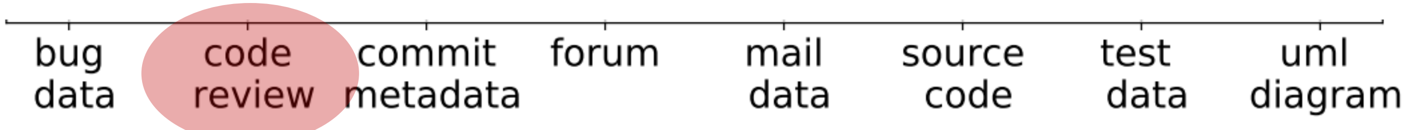
Auger: Automatically generating review comments with pre-training models

L Li, L Yang, H Jiang, J Yan, T Luo, Z Hua… - Proceedings of the 30th …, 2022 - dl.acm.org

Code review is one of the best practices as a powerful safeguard for software quality. In practice, senior or highly skilled reviewers inspect source code and provide constructive …

[ESEC/FSE 2022]



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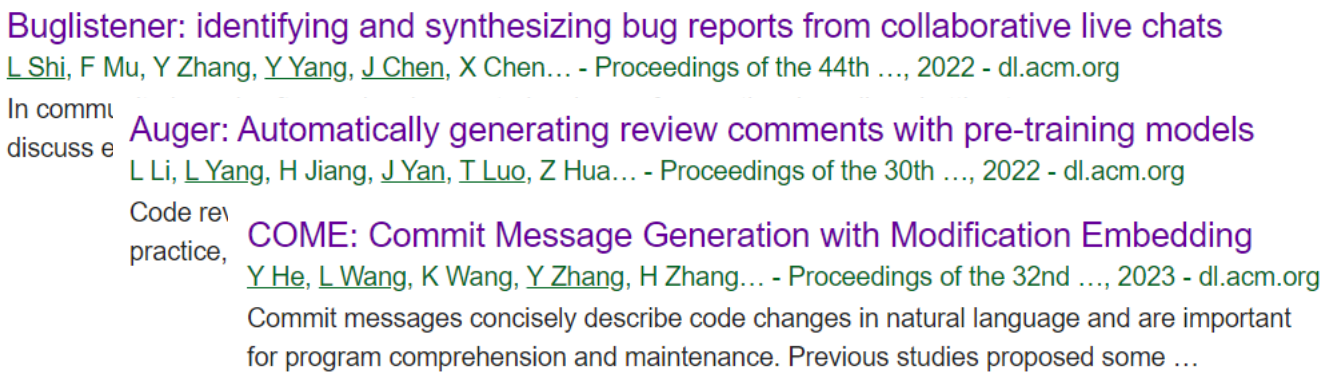

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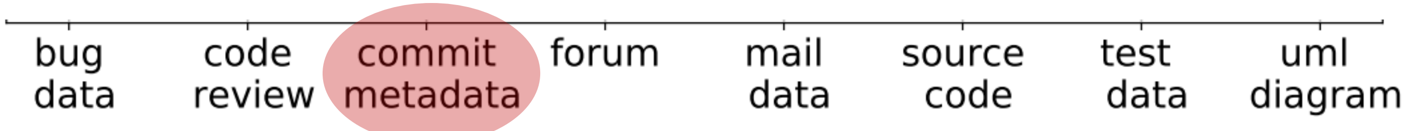
COME: Commit Message Generation with Modification Embedding

Y He, L Wang, K Wang, Y Zhang, H Zhang… - Proceedings of the 32nd …, 2023 - dl.acm.org

Commit messages concisely describe code changes in natural language and are important for program comprehension and maintenance. Previous studies proposed some …

[ISSTA 2023]



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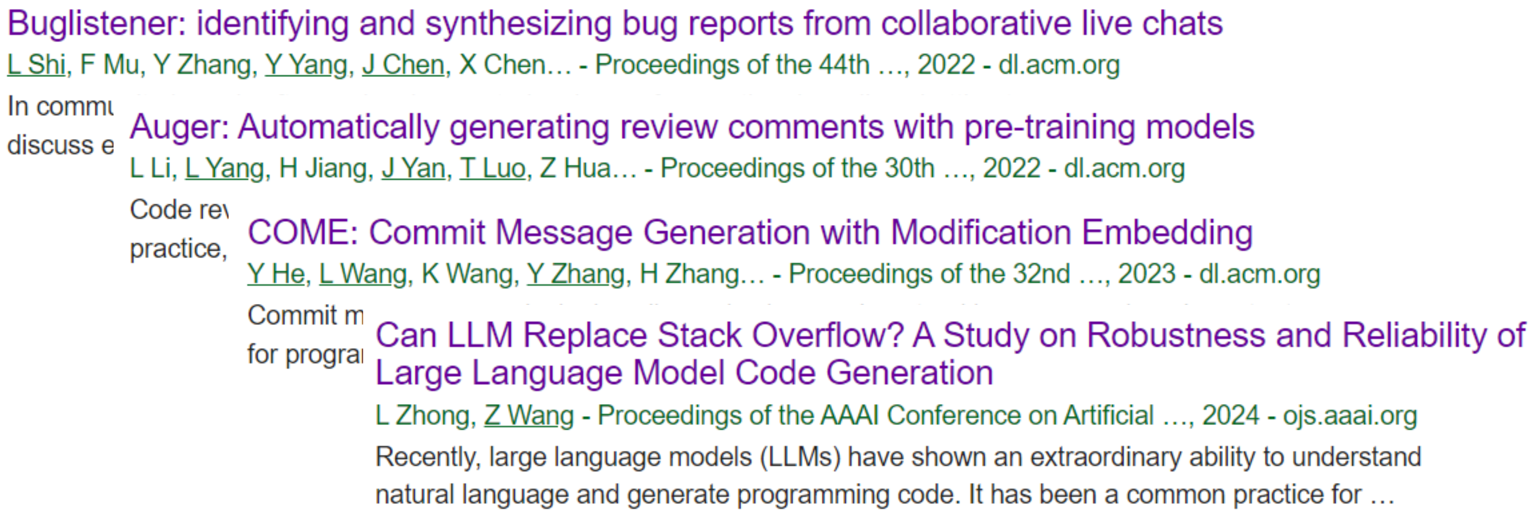

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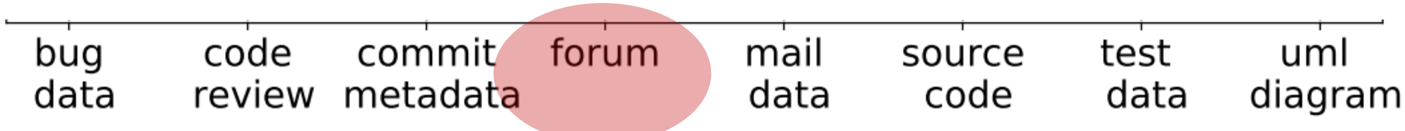
Can LLM Replace Stack Overflow? A Study on Robustness and Reliability of Large Language Model Code Generation

L Zhong, Z Wang - Proceedings of the AAAI Conference on Artificial …, 2024 - ojs.aaai.org

Recently, large language models (LLMs) have shown an extraordinary ability to understand natural language and generate programming code. It has been a common practice for …

[AAAI 2024]



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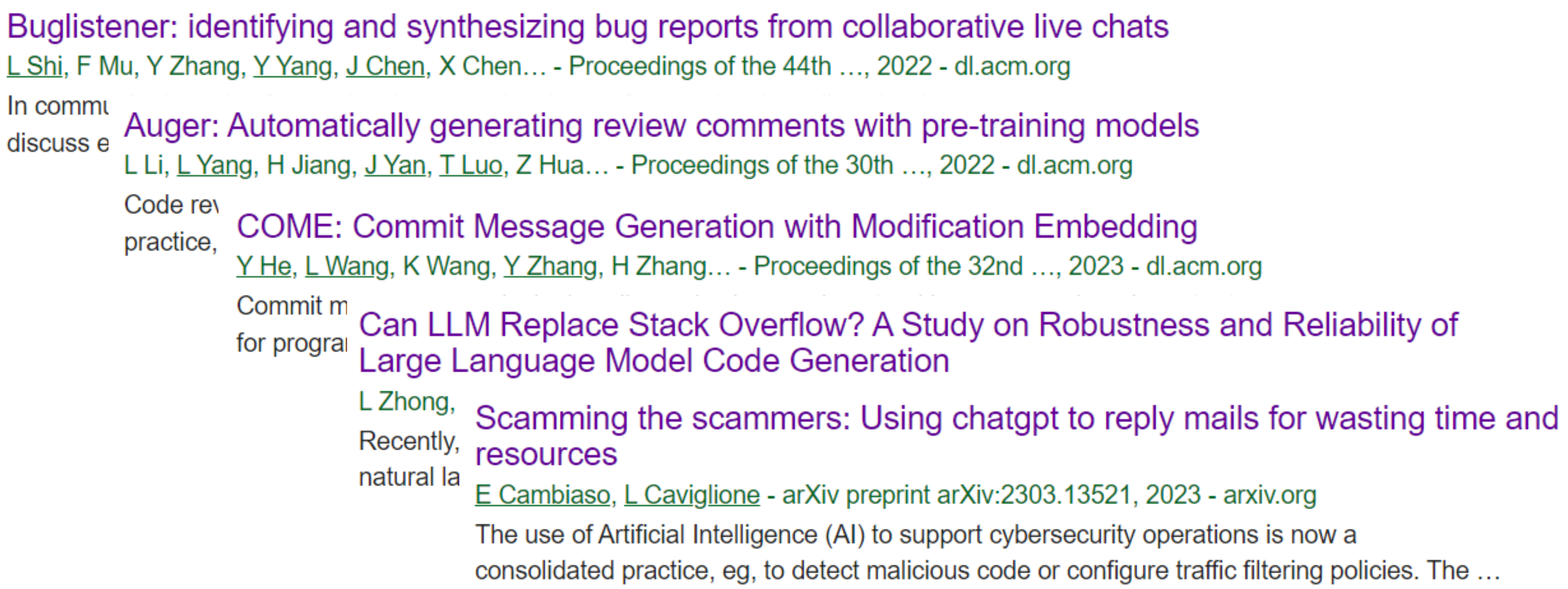

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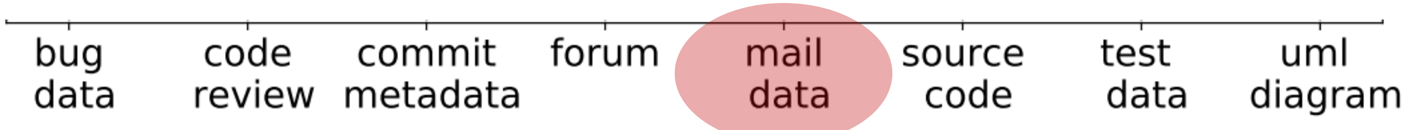
Scamming the scammers: Using chatgpt to reply mails for wasting time and resources

E Cambiaso, L Caviglione - arXiv preprint arXiv:2303.13521, 2023 - arxiv.org

The use of Artificial Intelligence (AI) to support cybersecurity operations is now a consolidated practice, eg, to detect malicious code or configure traffic filtering policies. The …

[arXiv 2023]



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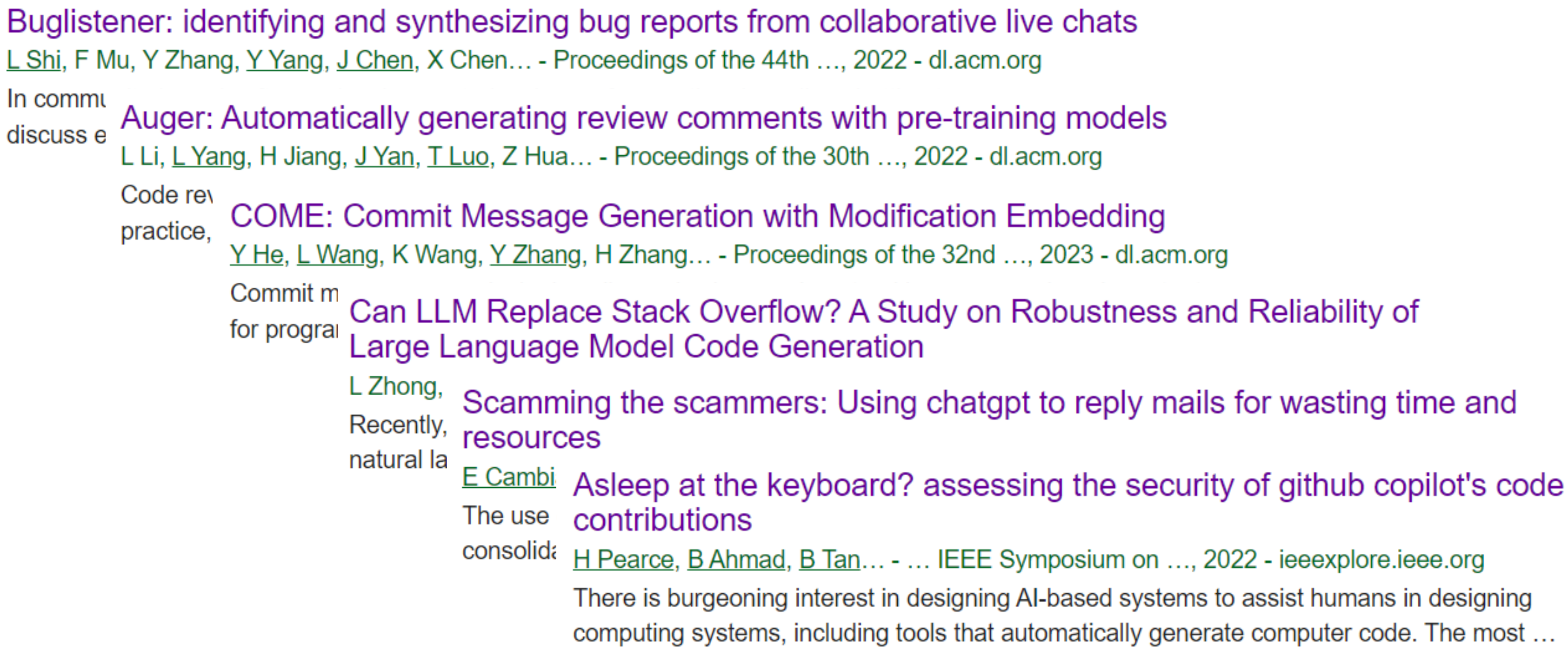

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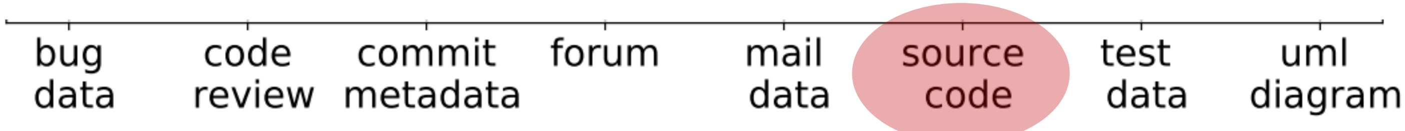
Asleep at the keyboard? assessing the security of github copilot's code contributions
H Pearce, B Ahmad, B Tan… - … IEEE Symposium on …, 2022 - ieeexplore.ieee.org
There is burgeoning interest in designing AI-based systems to assist humans in designing computing systems, including tools that automatically generate computer code. The most …

[SP 2022]



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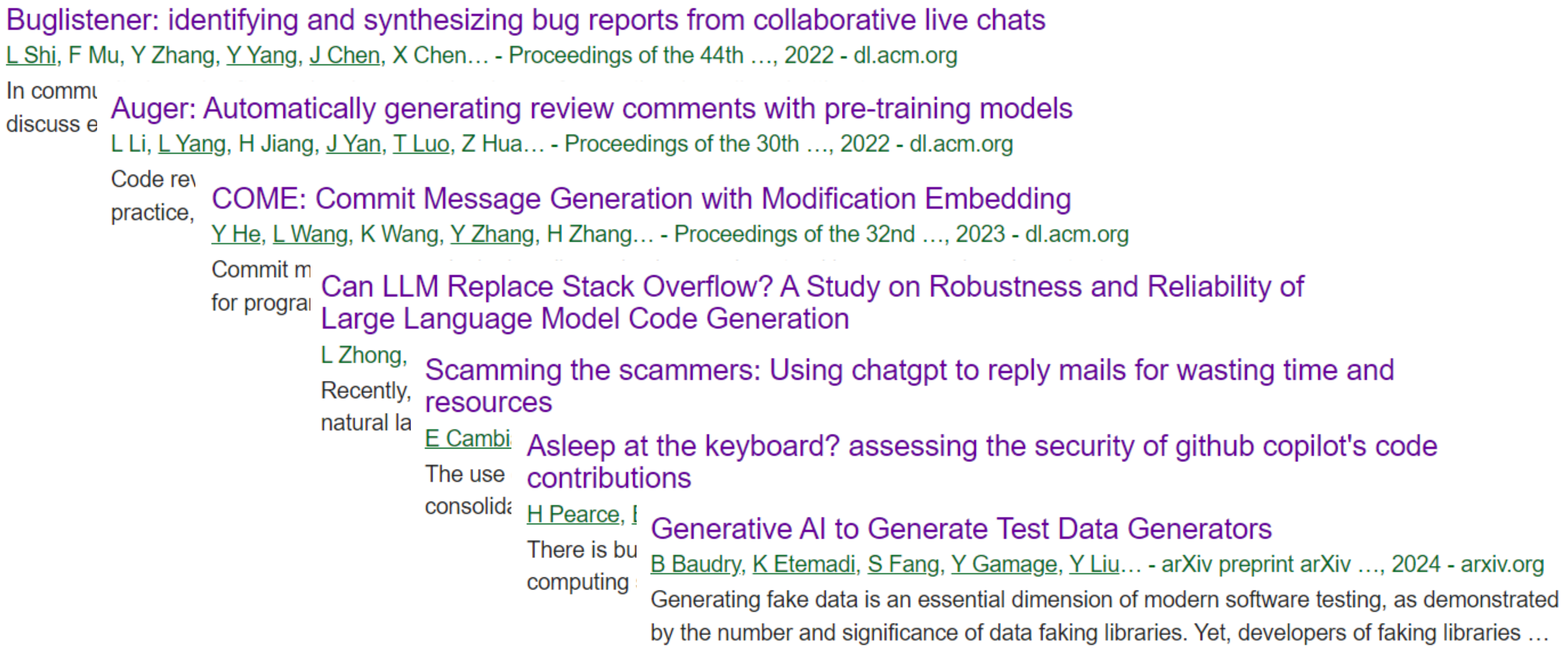

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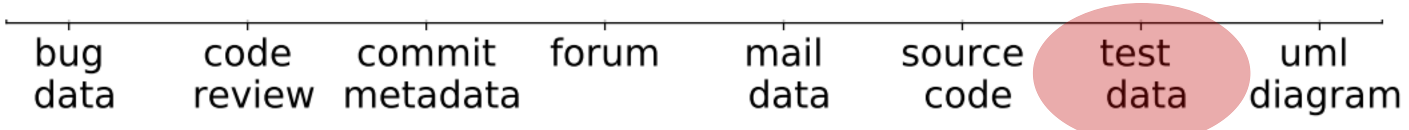
Generative AI to Generate Test Data Generators
B Baudry, K Etemadi, S Fang, Y Gamage, Y Liu… - arXiv preprint arXiv …, 2024 - arxiv.org
Generating fake data is an essential dimension of modern software testing, as demonstrated by the number and significance of data faking libraries. Yet, developers of faking libraries …

[arXiv 2024]



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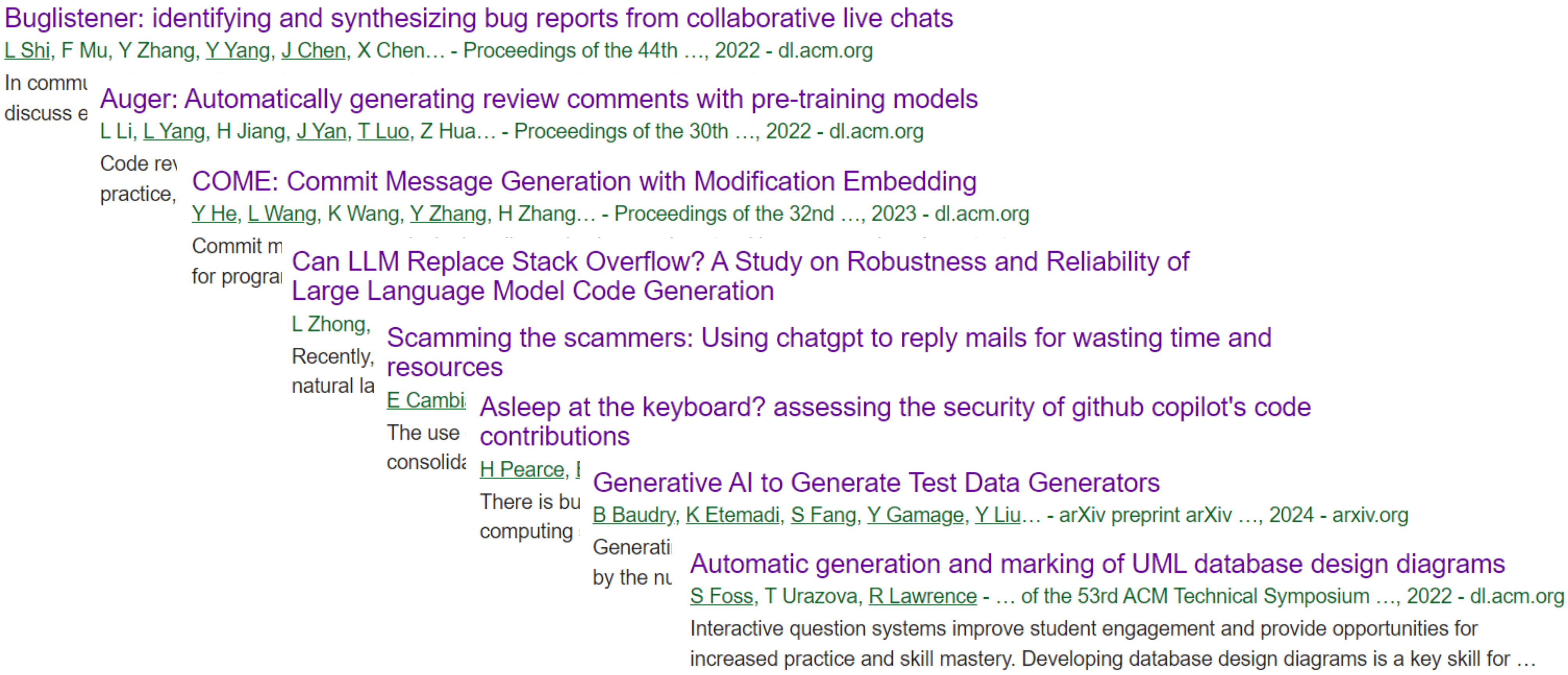

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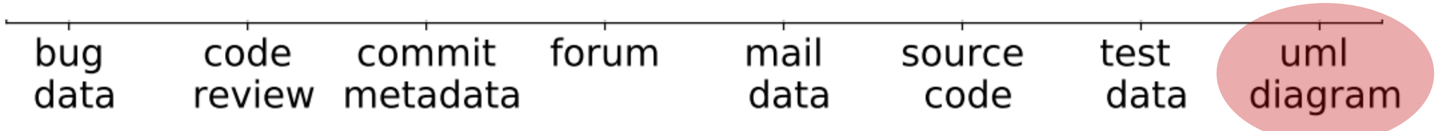
Automatic generation and marking of UML database design diagrams
S Foss, T Urazova, R Lawrence - … of the 53rd ACM Technical Symposium …, 2022 - dl.acm.org
Interactive question systems improve student engagement and provide opportunities for increased practice and skill mastery. Developing database design diagrams is a key skill for …

[SIGCSE 2022]



The Large Language Models Era

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> [Harrison and Basili]

The Large Language Models Era

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Are we just going to analyze LLM-generated output?

The Large Language Models Era

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[Harrison and Basili]

Are we just going to analyze LLM-generated output?

What is the role of Empirical Software Engineering Research in the LLM Era?

The Large Language Models Era

LLM

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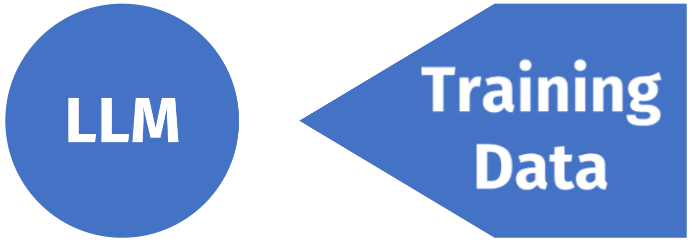

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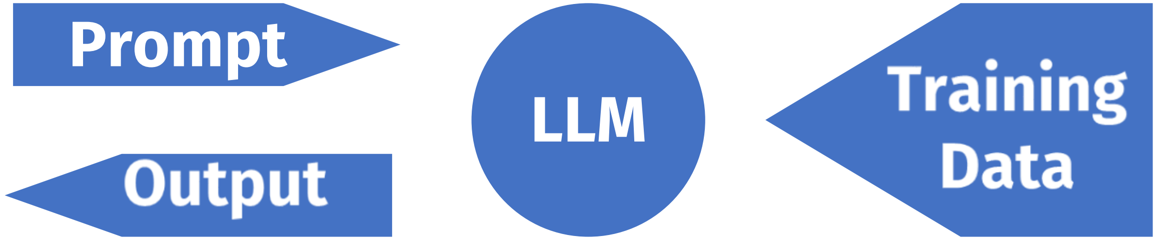

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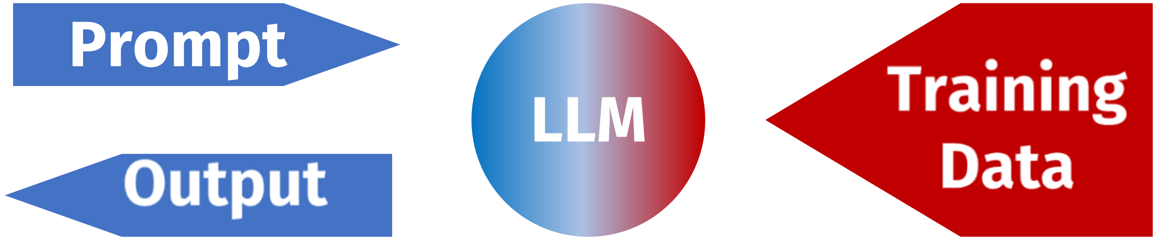
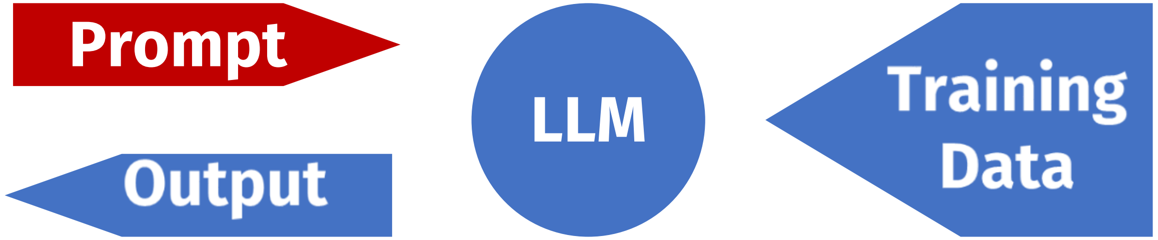
Analyzing the rich data available



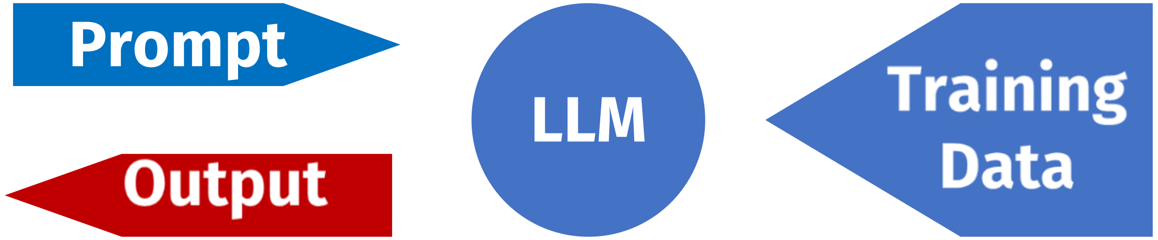
1) Analyze the training data and its impact on the LLM

Analyzing the rich data available

2) Analyze interaction with LLMs

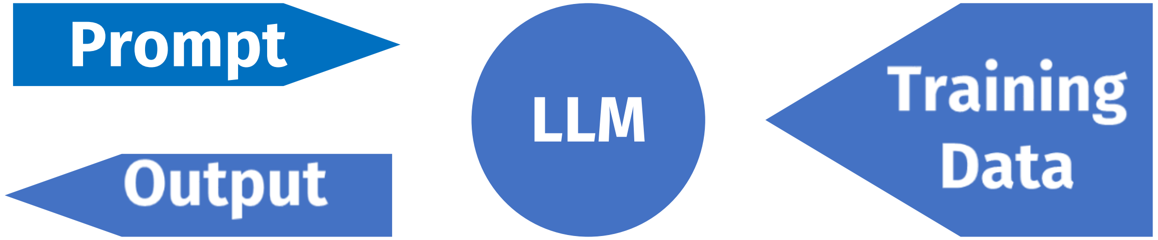


Analyzing the rich data available



3) Analyze LLM output

Analyzing the rich data available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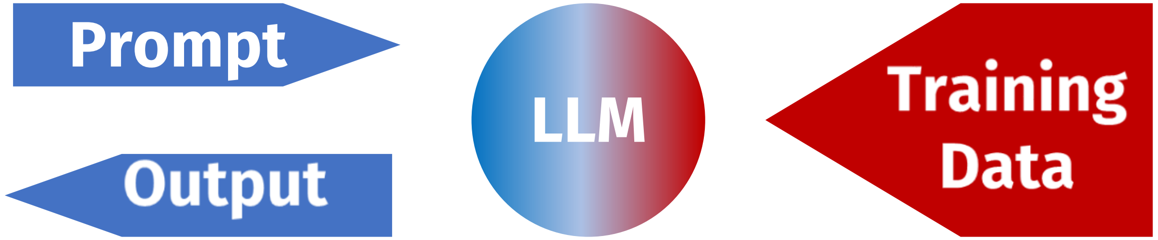
Output

LLM

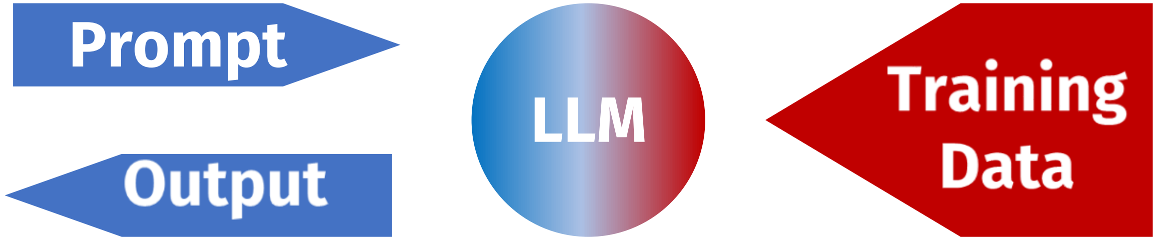
Training Data

4) The bigger picture?

Analyzing the training data & its impact



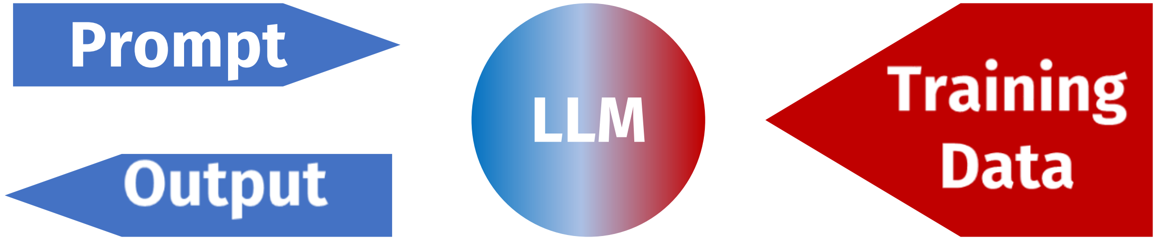
Analyzing the training data & its impact



[Treude and Hata, MSR 2023]

Analyzing the training data & its impact

require high standards and timeliness but offer
little substantive development or visibility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[Treude and Hata, MSR 2023]

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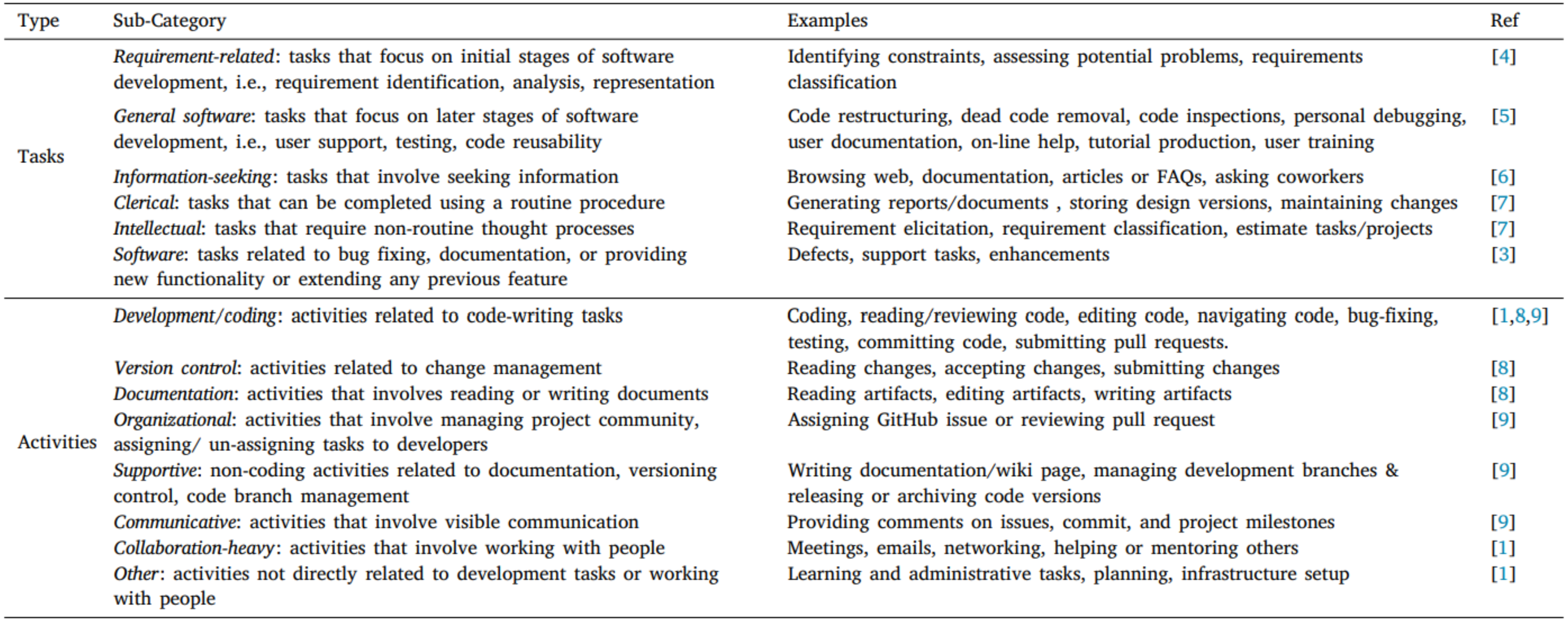
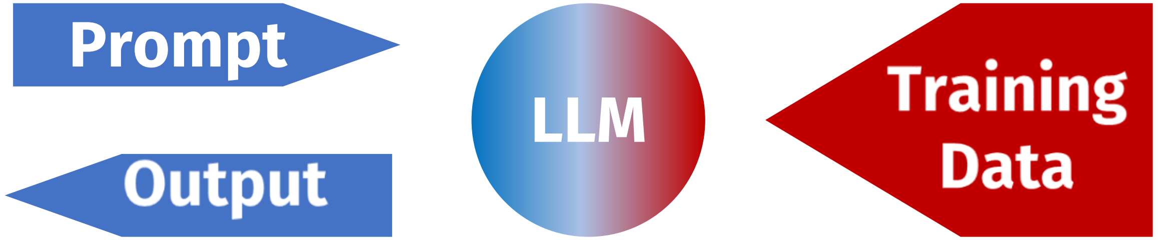


Type	Sub-Category	Examples	Ref
Tasks	*Requirement-related*: tasks that focus on initial stages of software development, i.e., requirement identification, analysis, representation	Identifying constraints, assessing potential problems, requirements classification	[4]
	General software: tasks that focus on later stages of software development, i.e., user support, testing, code reusability	Code restructuring, dead code removal, code inspections, personal debugging, user documentation, on-line help, tutorial production, user training	[5]
	Information-seeking: tasks that involve seeking information	Browsing web, documentation, articles or FAQs, asking coworkers	[6]
	Clerical: tasks that can be completed using a routine procedure	Generating reports/documents , storing design versions, maintaining changes	[7]
	Intellectual: tasks that require non-routine thought processes	Requirement elicitation, requirement classification, estimate tasks/projects	[7]
	Software: tasks related to bug fixing, documentation, or providing new functionality or extending any previous feature	Defects, support tasks, enhancements	[3]
Activities	*Development/coding*: activities related to code-writing tasks	Coding, reading/reviewing code, editing code, navigating code, bug-fixing, testing, committing code, submitting pull requests.	[1,8,9]
	Version control: activities related to change management	Reading changes, accepting changes, submitting changes	[8]
	Documentation: activities that involves reading or writing documents	Reading artifacts, editing artifacts, writing artifacts	[8]
	Organizational: activities that involve managing project community, assigning/ un-assigning tasks to developers	Assigning GitHub issue or reviewing pull request	[9]
	Supportive: non-coding activities related to documentation, versioning control, code branch management	Writing documentation/wiki page, managing development branches & releasing or archiving code versions	[9]
	Communicative: activities that involve visible communication	Providing comments on issues, commit, and project milestones	[9]
	Collaboration-heavy: activities that involve working with people	Meetings, emails, networking, helping or mentoring others	[1]
	Other: activities not directly related to development tasks or working with people	Learning and administrative tasks, planning, infrastructure setup	[1]



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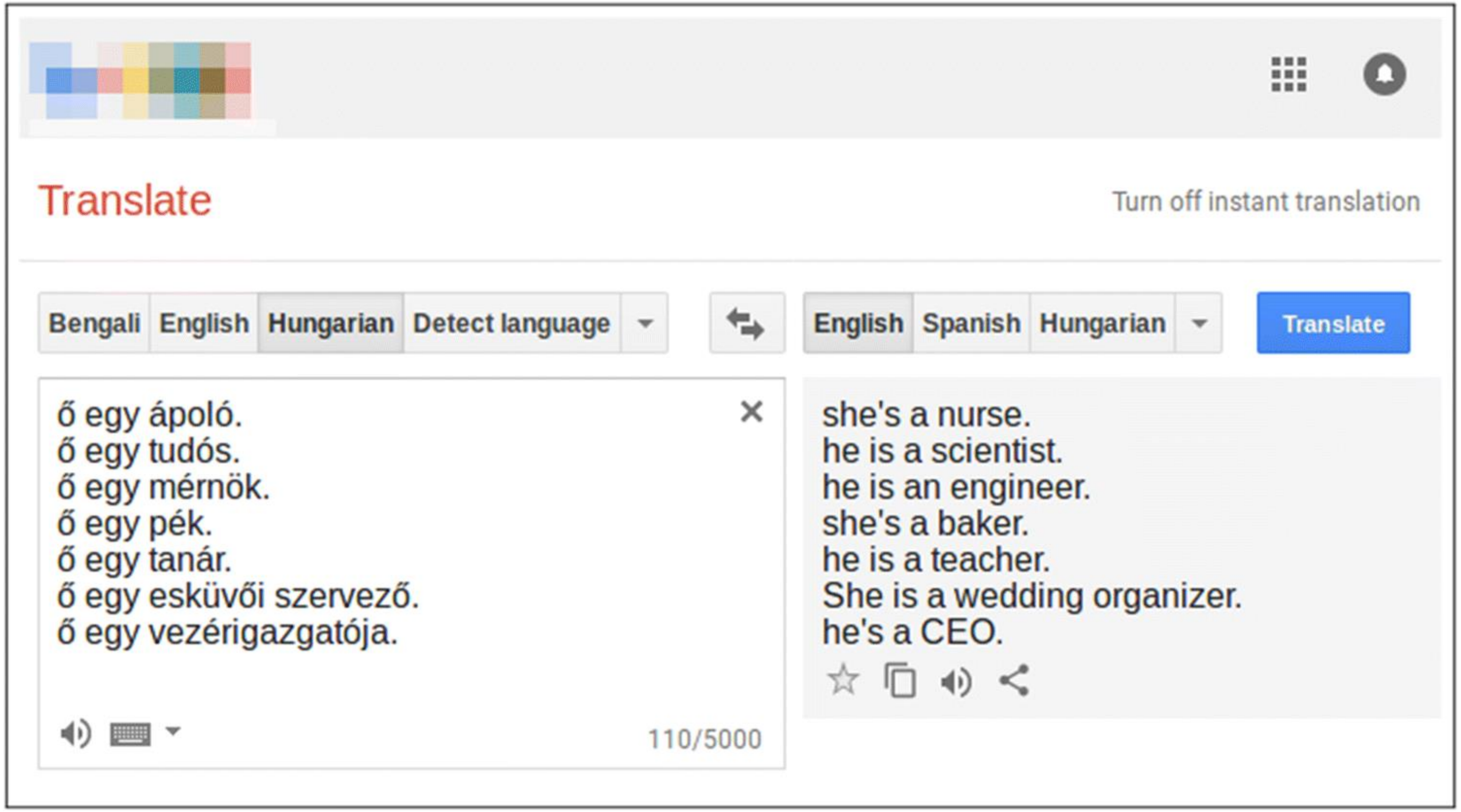
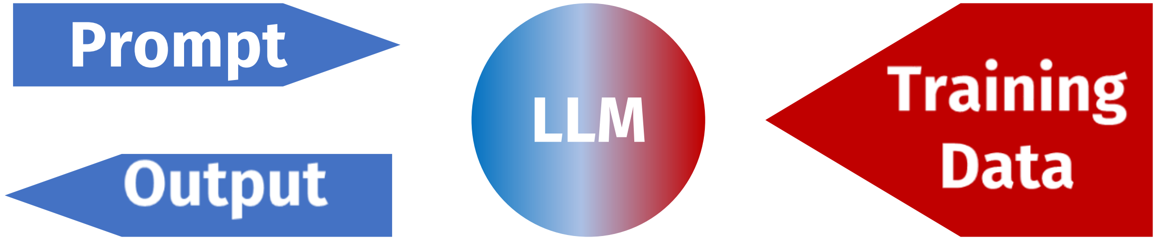
[Masood et al., IST 2022]

Analyzing the training data & its impact



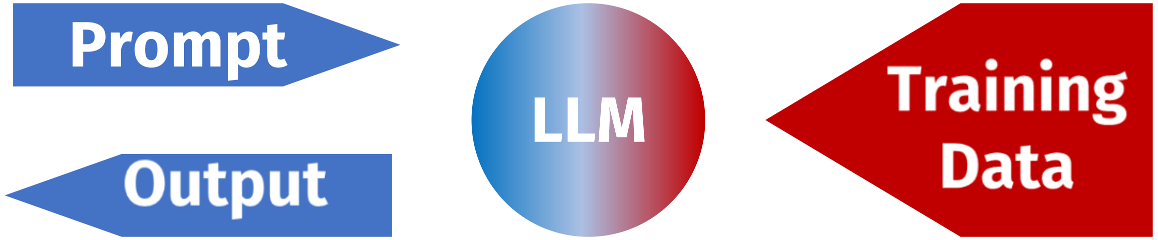
ő egy ápoló.
ő egy tudós.
ő egy mérnök.
ő egy pék.
ő egy tanár.
ő egy esküvői szervező.
ő egy vezérigazgatója.

she's a nurse.
he is a scientist.
he is an engineer.
she's a baker.
he is a teacher.
She is a wedding organizer.
he's a CEO.



[Treude and Hata, MSR 2023]

As a software engineer, she identifies constraints.
As a software engineer, she assesses potential problems.
As a software engineer, she classifies requirements.
As a software engineer, she restructures code.
As a software engineer, she removes dead code.
As a software engineer, she inspects code.
As a software engineer, she performs personal debugging.
As a software engineer, she produces user documentation.
As a software engineer, she produces on-line help.
As a software engineer, she produces tutorials.
As a software engineer, she performs user training.
As a software engineer, she browses the web.
As a software engineer, she browses documentation.
As a software engineer, she browses articles.
As a software engineer, she browses FAQs.
As a software engineer, she asks coworkers.
As a software engineer, she generates reports/documents.
As a software engineer, she stores design versions.
As a software engineer, she maintains changes.
As a software engineer, she elicits requirements.
As a software engineer, she estimates tasks/projects.
As a software engineer, she fixes defects.
As a software engineer, she performs support tasks.
As a software engineer, she provides enhancements.
As a software engineer, she codes.
As a software engineer, she reads/reviews code.
As a software engineer, she edits code.
As a software engineer, she navigates code.
As a software engineer, she fixes bugs.
As a software engineer, she tests.
As a software engineer, she commits code.
As a software engineer, she submits pull requests.
As a software engineer, she reads changes.
As a software engineer, she accepts changes.
As a software engineer, she submits changes.
As a software engineer, she reads artifacts.
As a software engineer, she edits artifacts.
As a software engineer, she writes artifacts.
As a software engineer, she assigns GitHub issues.
As a software engineer, she reviews pull requests.
As a software engineer, she writes documentation/wiki pages.
As a software engineer, she manages development branches.
As a software engineer, she releases code versions.
As a software engineer, she archives code versions.
As a software engineer, she provides comments on issues.
As a software engineer, she provides comments on commits.
As a software engineer, she provides comments on project milestones.
As a software engineer, she has meetings.
As a software engineer, she writes emails.
As a software engineer, she networks.
As a software engineer, she helps others.
As a software engineer, she mentors others.
As a software engineer, she learns.
As a software engineer, she performs administrative tasks.
As a software engineer, she plans.
As a software engineer, she performs infrastructure setup.



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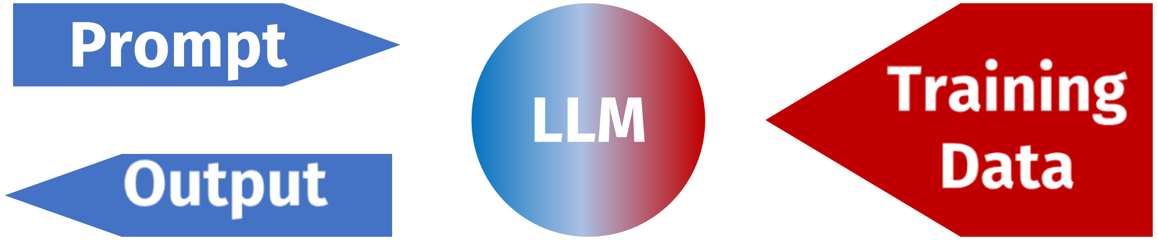
As a software engineer, she removes dead code.
As a software engineer, she inspects code.
As a software engineer, she performs personal debugging.
As a software engineer, she produces user documentation.
As a software engineer, she produces on-line help.
As a software engineer, she produces tutorials.
As a software engineer, she performs user training.
As a software engineer, she browses the web.
As a software engineer, she browses documentation.
As a software engineer, she browses articles.
As a software engineer, she browses FAQs.
As a software engineer, she asks coworkers.
As a software engineer, she generates reports/documents.
As a software engineer, she stores design versions.
As a software engineer, she maintains changes.
As a software engineer, she elicits requirements.
As a software engineer, she estimates tasks/projects.
As a software engineer, she fixes defects.
As a software engineer, she performs support tasks.
As a software engineer, she provides enhancements.
As a software engineer, she codes.
As a software engineer, she reads/reviews code.
As a software engineer, she edits code.
As a software engineer, she navigates code.
As a software engineer, she fixes bugs.
As a software engineer, she tests.
As a software engineer, she commits code.
As a software engineer, she submits pull requests.
As a software engineer, she reads changes.
As a software engineer, she accepts changes.
As a software engineer, she submits changes.
As a software engineer, she reads artifacts.
As a software engineer, she edits artifacts.
As a software engineer, she writes artifacts.
As a software engineer, she assigns GitHub issues.
As a software engineer, she reviews pull requests.
As a software engineer, she writes documentation/wiki pages.
As a software engineer, she manages development branches.
As a software engineer, she releases code versions.
As a software engineer, she archives code versions.
As a software engineer, she provides comments on issues.
As a software engineer, she provides comments on commits.
As a software engineer, she provides comments on project milestones.
As a software engineer, she has meetings.
As a software engineer, she writes emails.
As a software engineer, she networks.
As a software engineer, she helps others.
As a software engineer, she mentors others.
As a software engineer, she learns.
As a software engineer, she performs administrative tasks.
As a software engineer, she plans.
As a software engineer, she performs infrastructure setup.

As a software engineer, she elicits requirements.

As a software engineer, she tests.

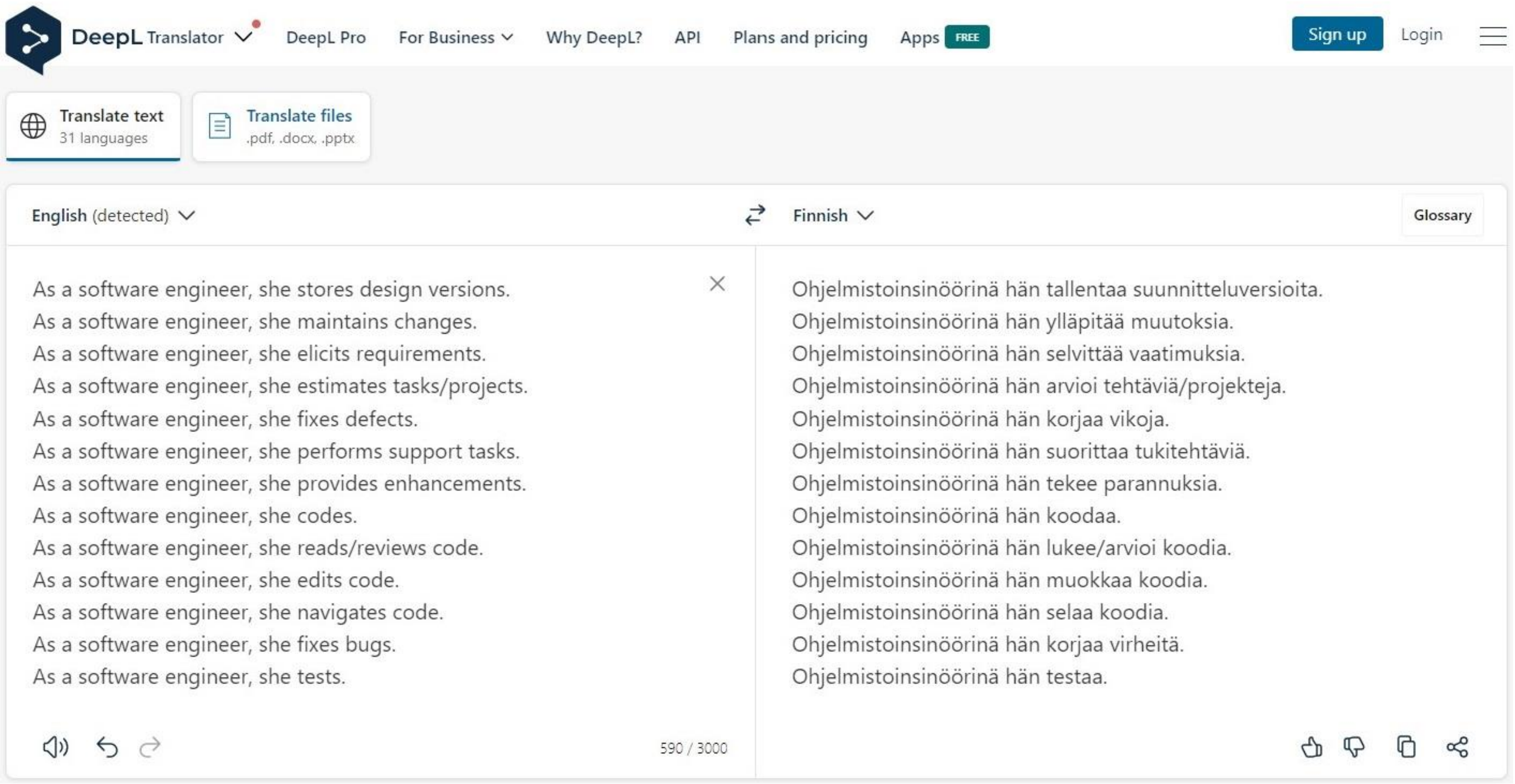

Prompt

Output

LLM

Training Data

Analyzing the training data & its impact



As a software engineer, she stores design versions.
As a software engineer, she maintains changes.
As a software engineer, she elicits requirements.
As a software engineer, she estimates tasks/projects.
As a software engineer, she fixes defects.
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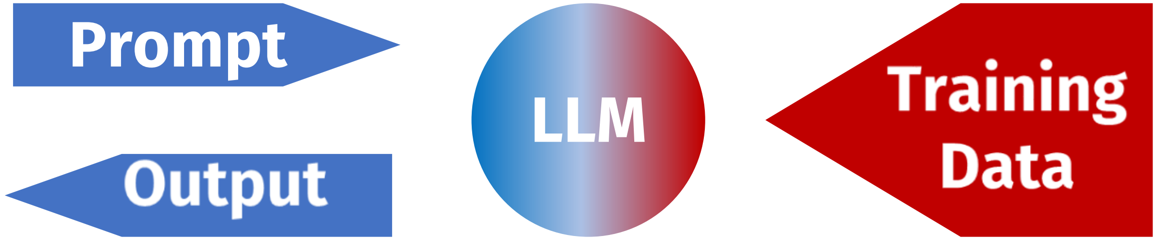
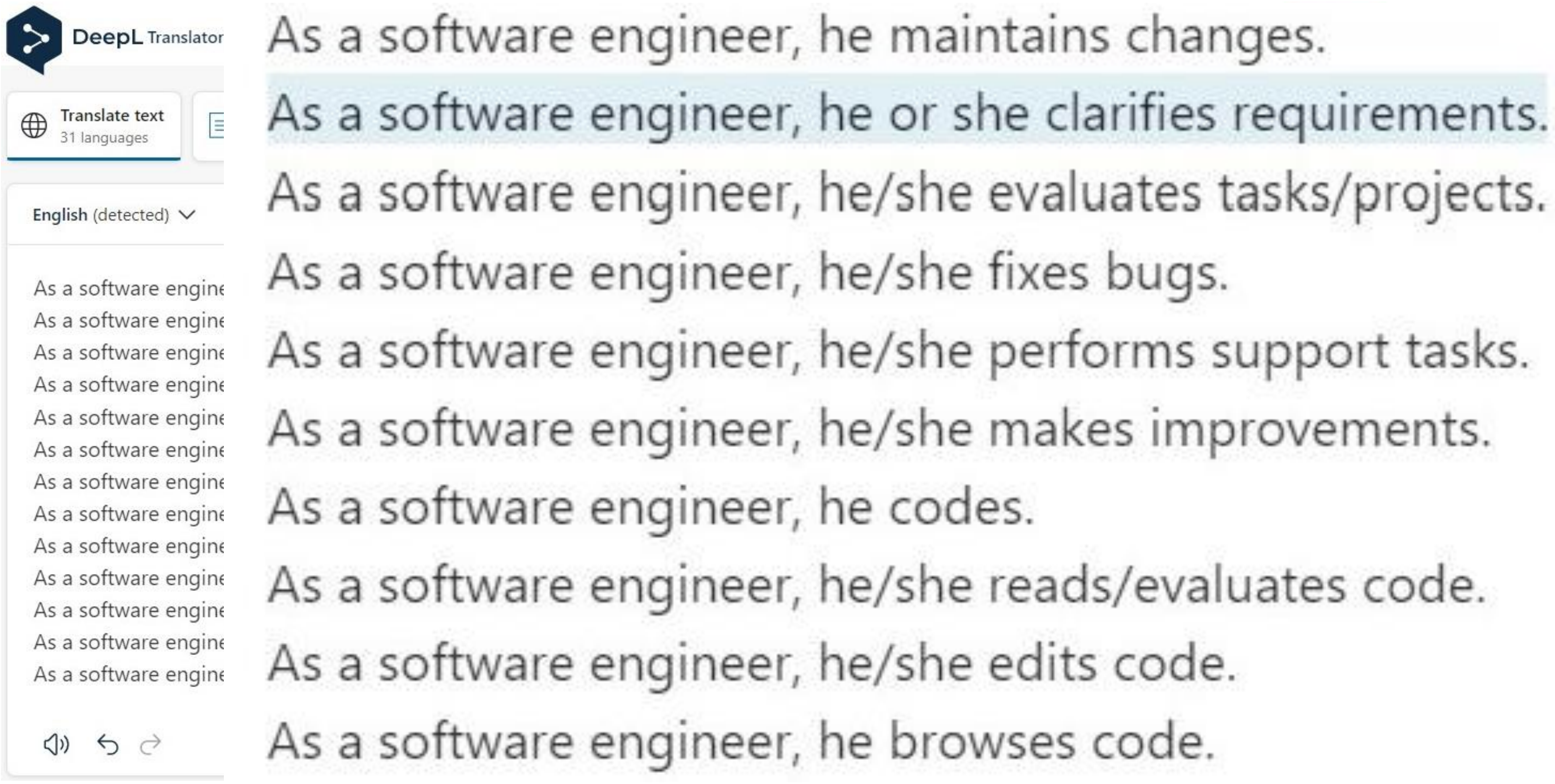
As a software engineer, she provides enhancements.
As a software engineer, she codes.
As a software engineer, she reads/reviews code.
As a software engineer, she edits code.
As a software engineer, she navigates code.
As a software engineer, she fixes bugs.
As a software engineer, she tests.

Ohjelmistoinsinöörinä hän tallentaa suunnitteluversioita.
Ohjelmistoinsinöörinä hän ylläpitää muutoksia.
Ohjelmistoinsinöörinä hän selvittää vaatimuksia.
Ohjelmistoinsinöörinä hän arvioi tehtäviä/projekteja.
Ohjelmistoinsinöörinä hän korjaa vikoja.
Ohjelmistoinsinöörinä hän suorittaa tukitehtäviä.
Ohjelmistoinsinöörinä hän tekee parannuksia.
Ohjelmistoinsinöörinä hän koodaa.
Ohjelmistoinsinöörinä hän lukee/arvioi koodia.
Ohjelmistoinsinöörinä hän muokkaa koodia.
Ohjelmistoinsinöörinä hän selaa koodia.
Ohjelmistoinsinöörinä hän korjaa virheitä.
Ohjelmistoinsinöörinä hän testaa.

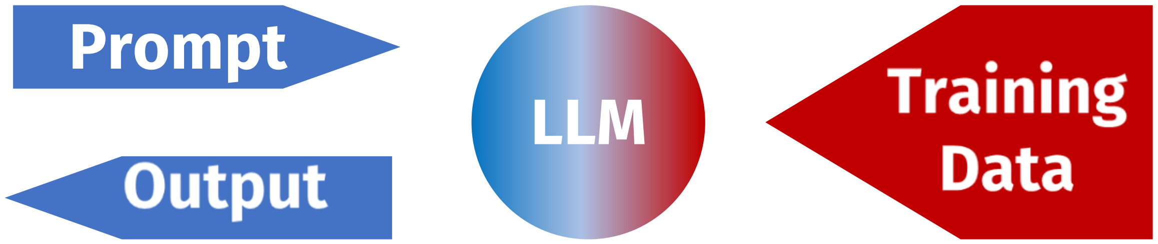


[Treude and Hata, MSR 2023]

Analyzing the training data & its impact



As a software engineer, he maintains changes.
As a software engineer, he or she clarifies requirements.
As a software engineer, he/she evaluates tasks/projects.
As a software engineer, he/she fixes bugs.
As a software engineer, he/she performs support tasks.
As a software engineer, he/she makes improvements.
As a software engineer, he codes.
As a software engineer, he/she reads/evaluates code.
As a software engineer, he/she edits code.
As a software engineer, he browses code.



Prompt

Output

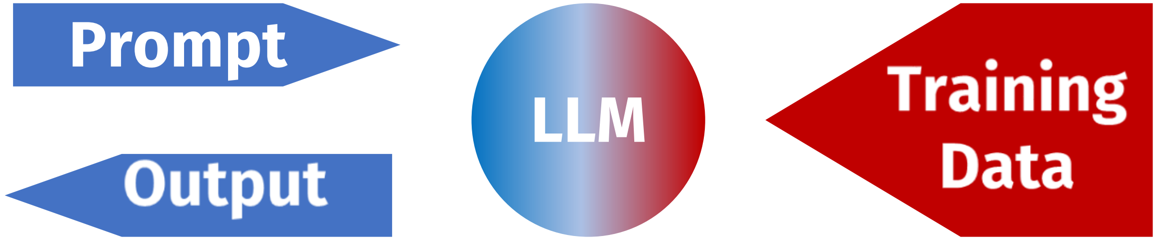
LLM

Training Data

[Treude and Hata, MSR 2023]

Analyzing the training data & its impact

Original Sentence	"she"	"he/she"	"he or she"	"he"
She elicits requirements.	0	51	43	6
She estimates tasks/projects.	0	61	0	39
She performs infrastructure setup.	0	39	14	47
She performs support tasks.	0	44	6	49
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…
She learns.	0	0	0	100
She provides comments on issues.	0	0	0	100
She tests.	0	0	0	100

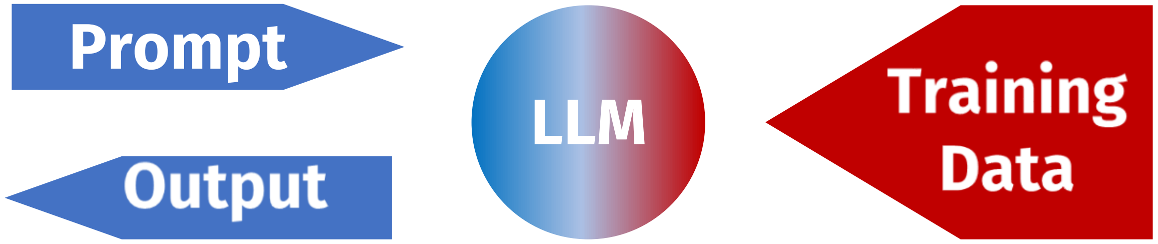


[Treude and Hata, MSR 2023]

Analyzing the training data & its impact

Heuristics don’t address the underlying problem

Lots of other potential biases, e.g., feature prioritization



[Treude and Hata, MSR 2023]

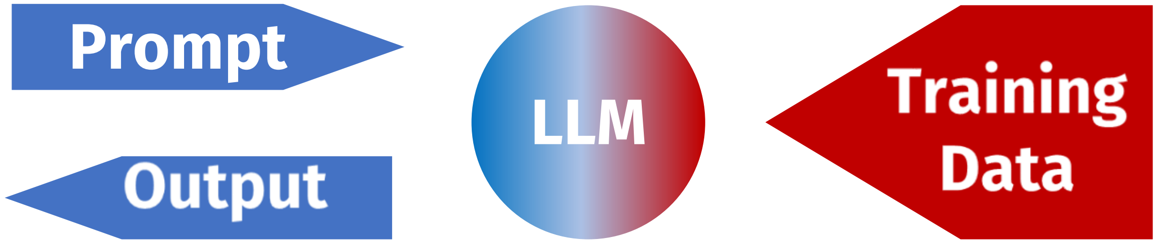
Analyzing the training data & its impact

Heuristics don't address the underlying problem

Consider ethical dilemmas

Lots of other potential biases, e.g., feature prioritization

Causal relationships between training data and LLMs



[Treude and Hata, MSR 2023]

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Lots of oth
potential bia
e.g., featu
prioritizati

Nigerian Software Engineer or American Data Scientist? GitHub Profile Recruitment Bias in Large Language Models

Takashi Nakano
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Christoph Treude
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Australia
marc.cheong@unimelb.edu.au

Kenichi Matsumoto
Nara Institute of Science and Technology
Japan
matumoto@is.naist.jp

[Nakano et al., ICSME 2024]

Analyzing the training data & its impact

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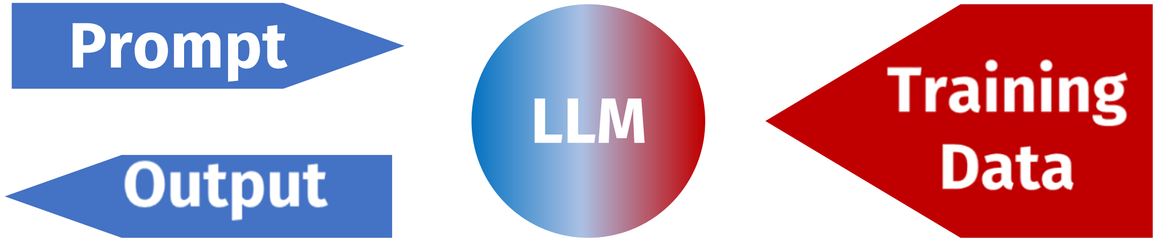

[Treude and Hata, MSR 2023]

Analyzing the training data & its impact

Heuristics don’t
address the
underlying
problem

C r ethical
lemmas

We know the data!

Lots of ot
potential s,
e.g., feat re
prioritization

Causal
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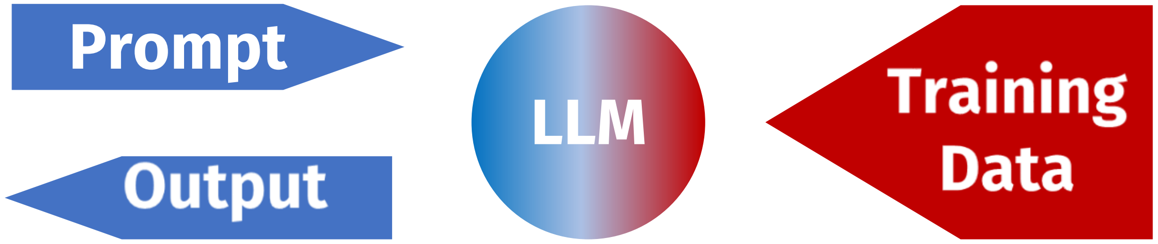
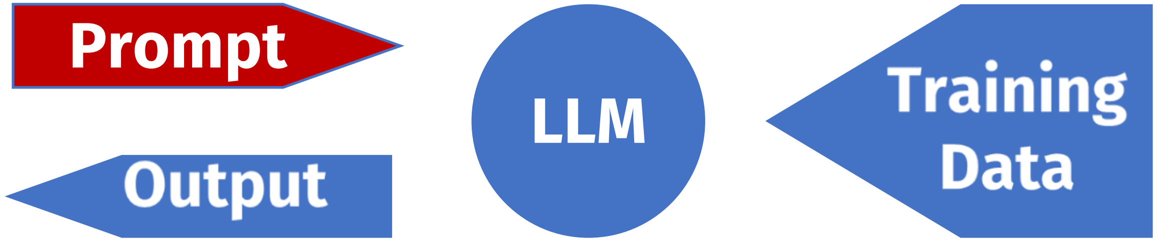
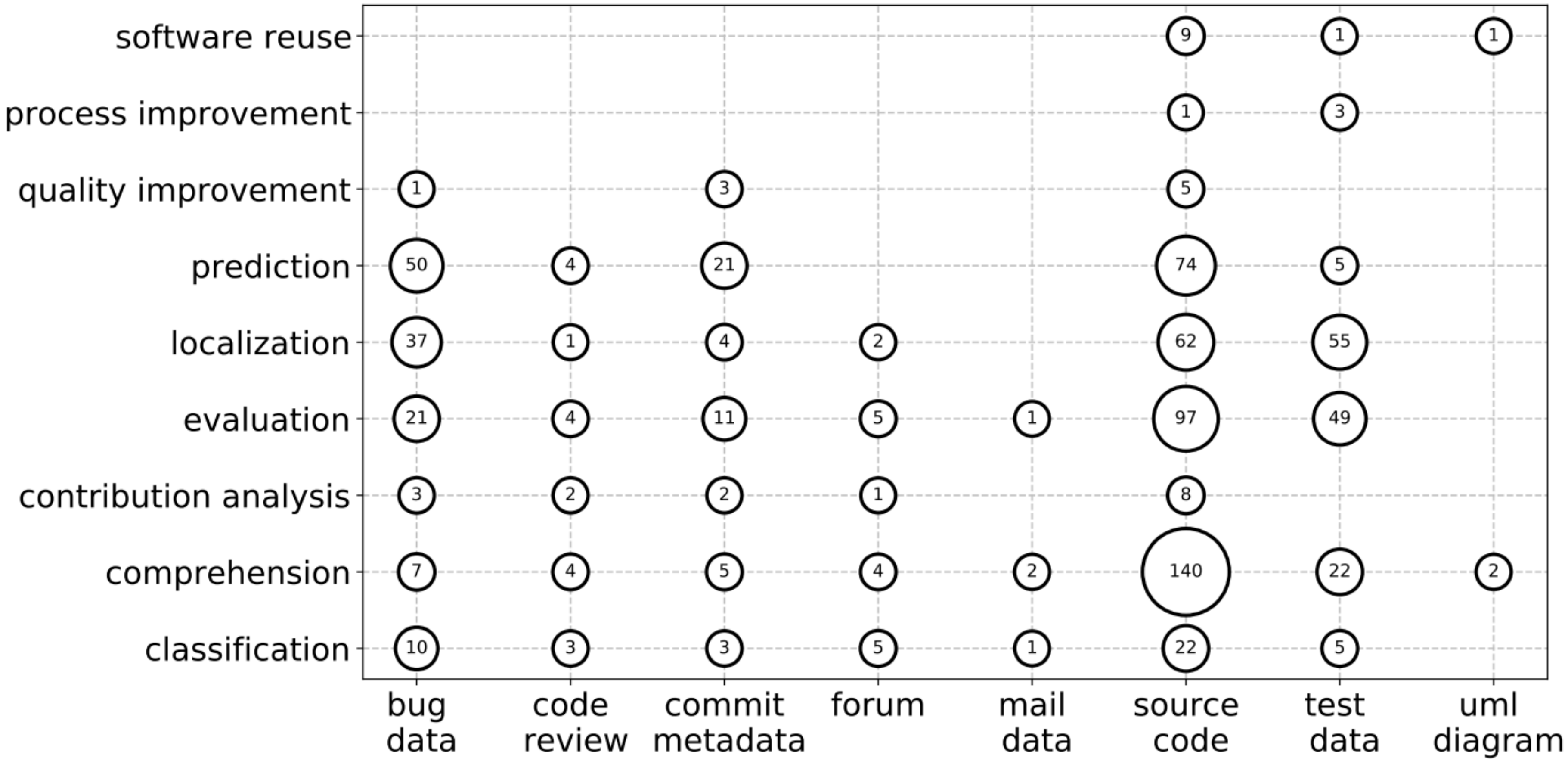


[Treude and Hata, MSR 2023]

Analyzing interactions with LLMs



Analyzing interactions with ~~LLMs~~ artifacts



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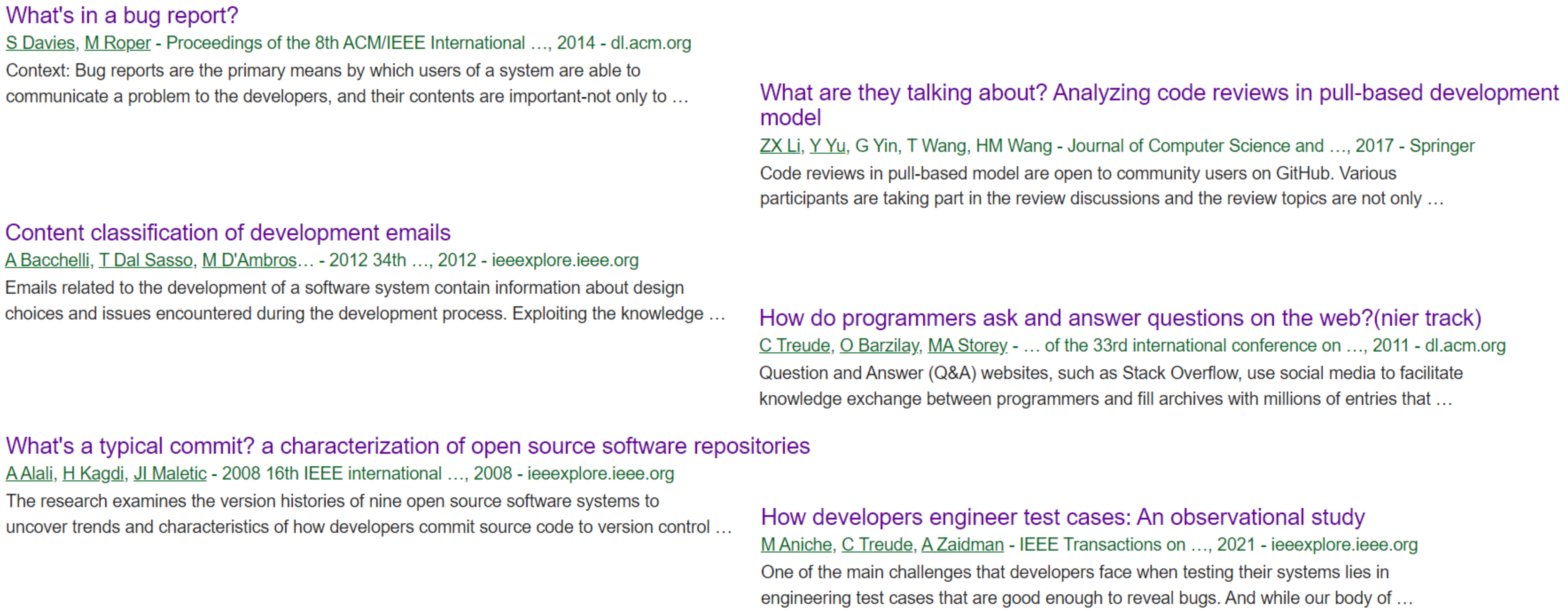

What's in a bug report?

S Davies, M Roper - Proceedings of the 8th ACM/IEEE International …, 2014 - dl.acm.org

Context: Bug reports are the primary means by which users of a system are able to communicate a problem to the developers, and their contents are important-not only to …

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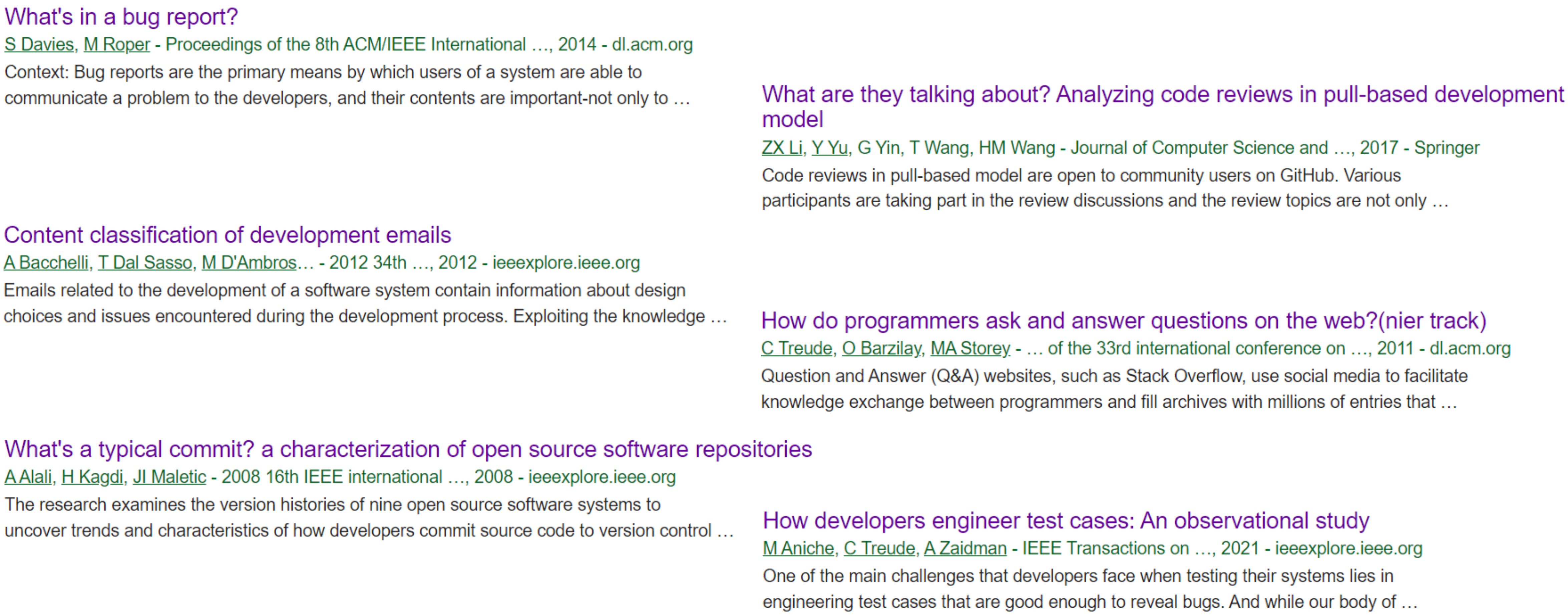

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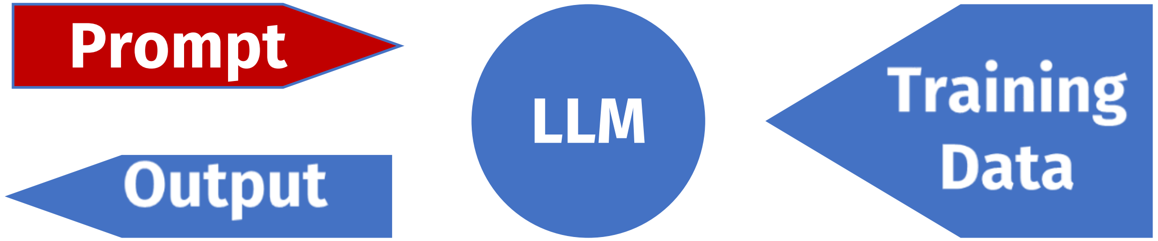
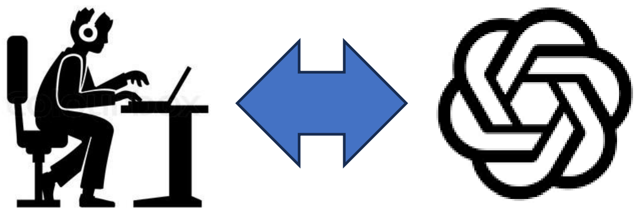
Mining Challenge: **DevGPT**

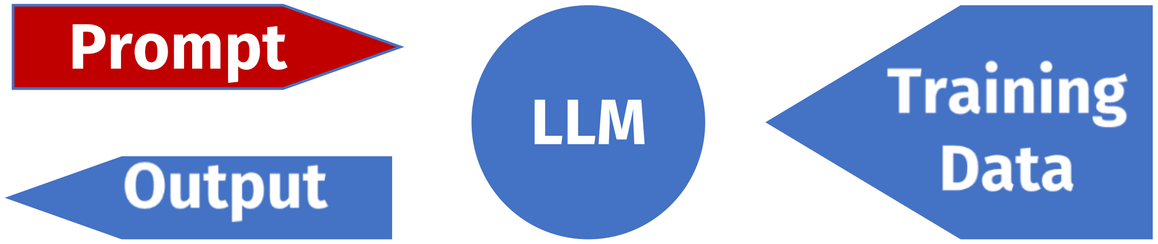


[Xiao et al., MSR 2024]

How do developers interact with LLMs?

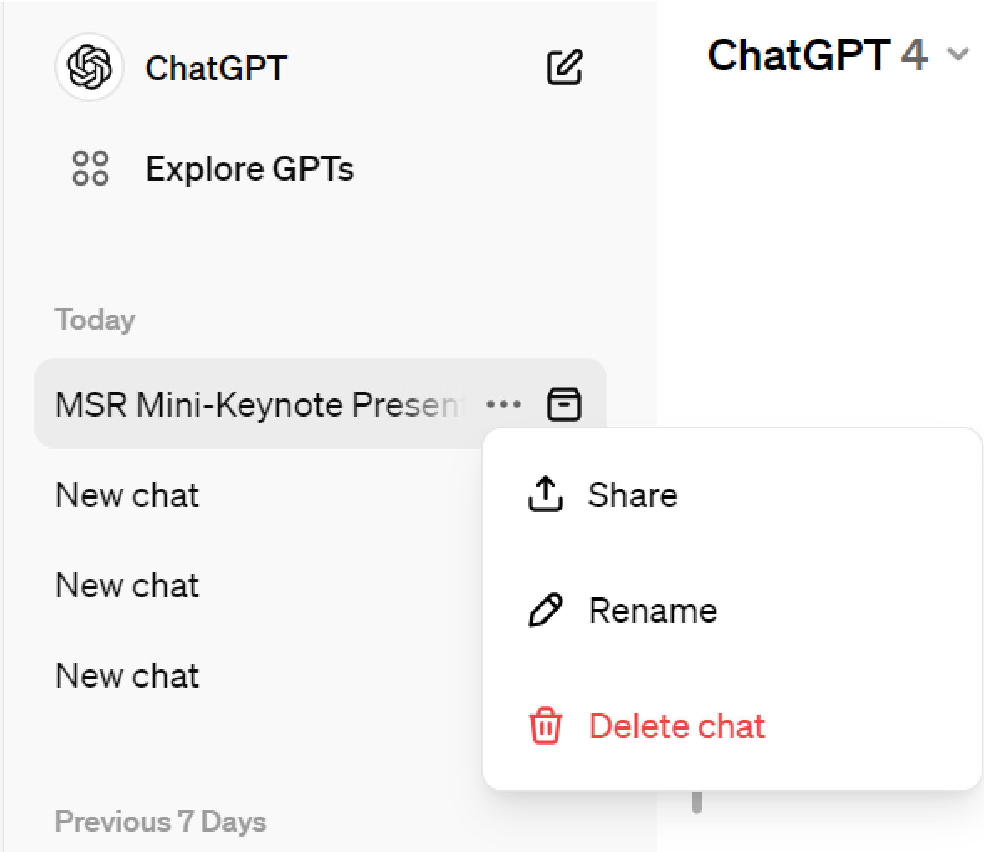
Mining Challenge: **DevGPT**

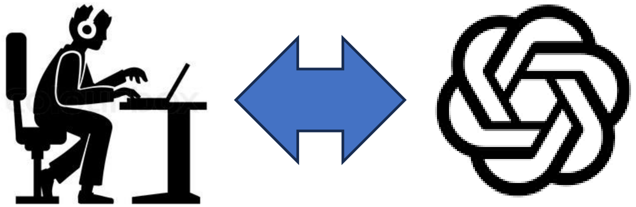




[Xiao et al., MSR 2024]

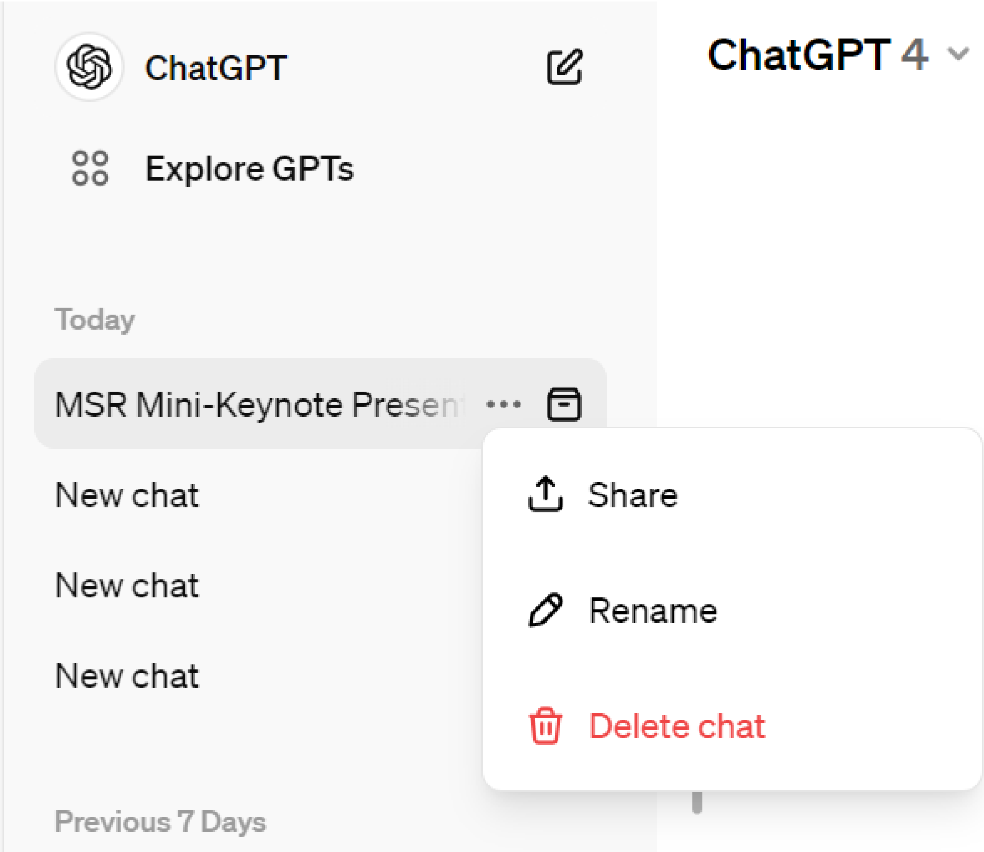
How do developers interact with LLMs?

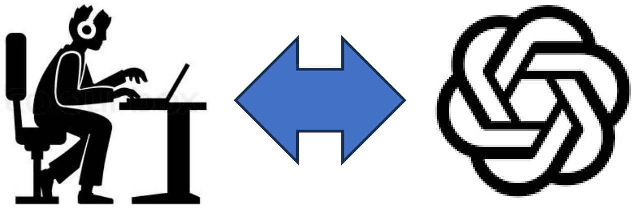




[Xiao et al., MSR 2024]

How do developers interact with LLMs?

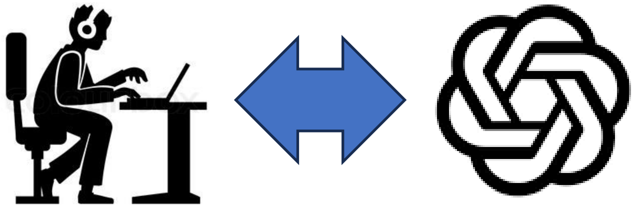




[Xiao et al., MSR 2024]

How do developers interact with LLMs?

	Links	Prompts	Code Snippets
Source Code	2,708	22,799	14,132
Commits	694	1,922	1,828
Issues	636	2,365	1,739
Pull Requests	301	1,160	975
Discussions	70	259	188
Hacker News	324	1,273	244
	4,733	**29,778**	**19,106**



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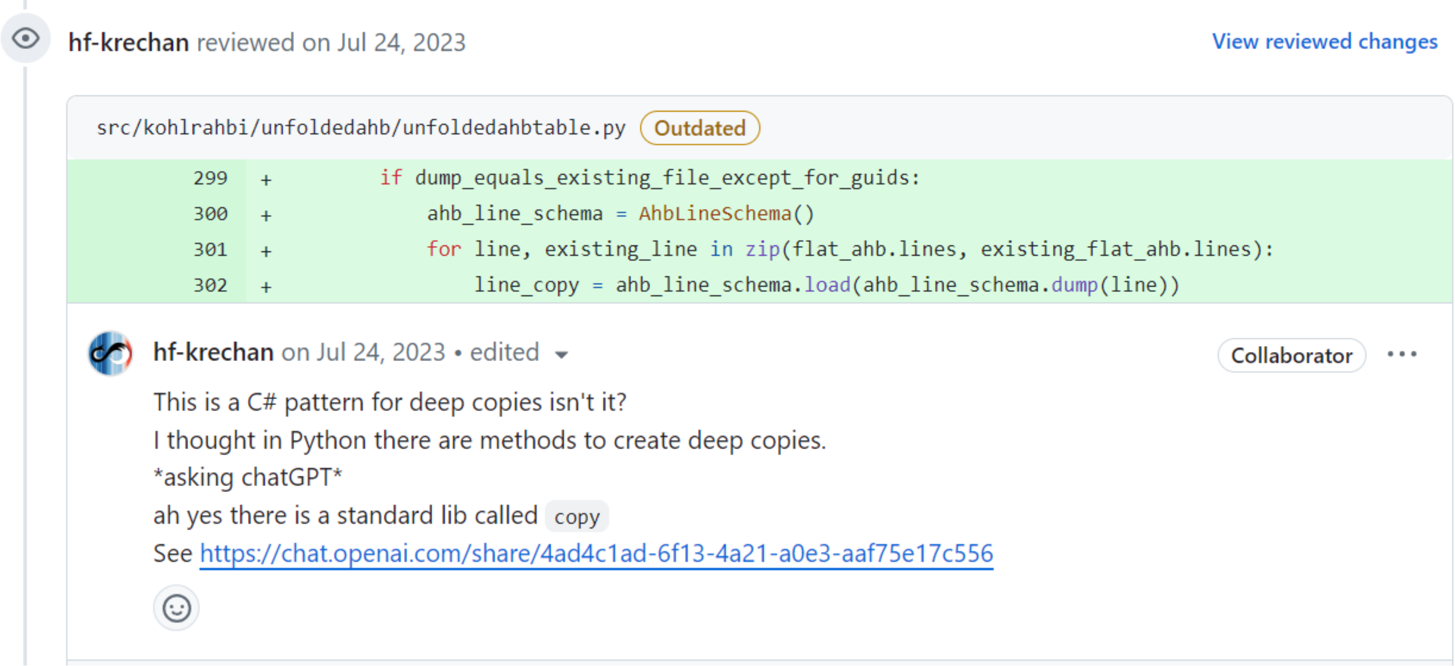

hf-krechan reviewed on Jul 24, 2023
View reviewed changes
Outdated

src/kohlrahbi/unfoldedahb/unfoldedahbtable.py

```
+        if dump_equals_existing_file_except_for_guids:
+            ahb_line_schema = AhbLineSchema()
+            for line, existing_line in zip(flat_ahb.lines, existing_flat_ahb.lines):
+                line_copy = ahb_line_schema.load(ahb_line_schema.dump(line))
```

hf-krechan on Jul 24, 2023 • edited
Collaborator

This is a C# pattern for deep copies isn't it?
I thought in Python there are methods to create deep copies.
asking chatGPT
ah yes there is a standard lib called `copy`
See https://chat.openai.com/share/4ad4c1ad-6f13-4a21-a0e3-aaf75e17c556

[Xiao et al., MSR 2024]

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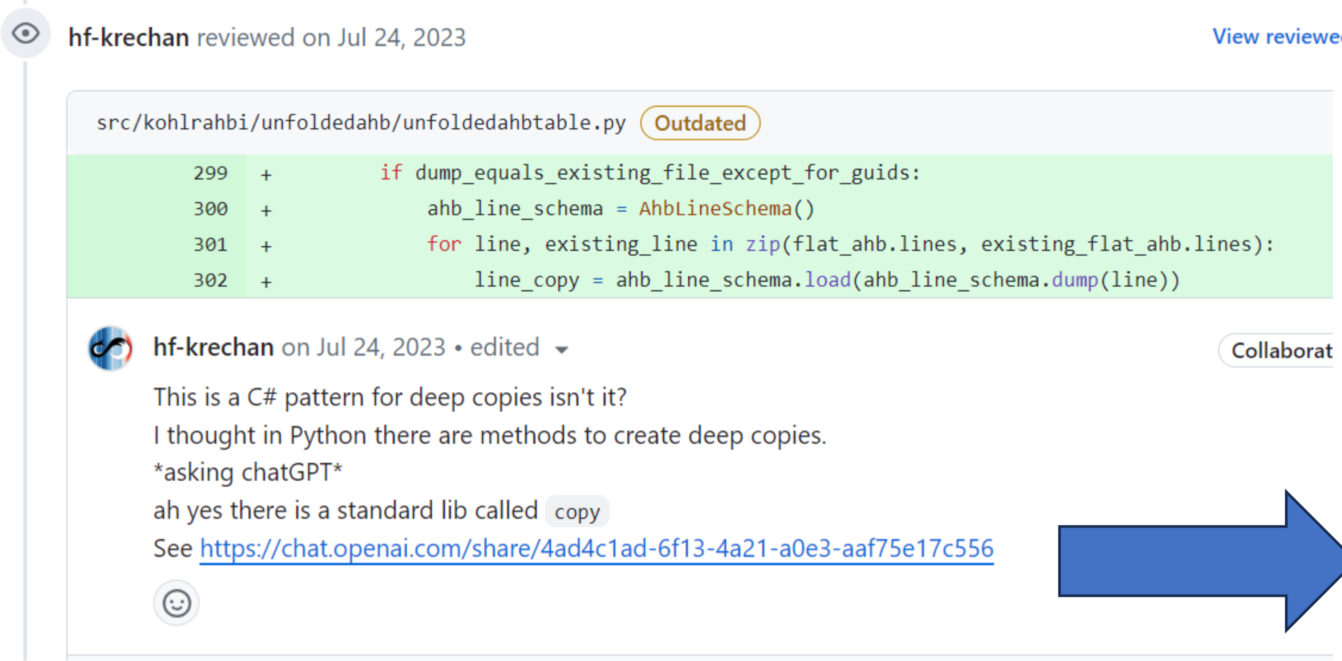

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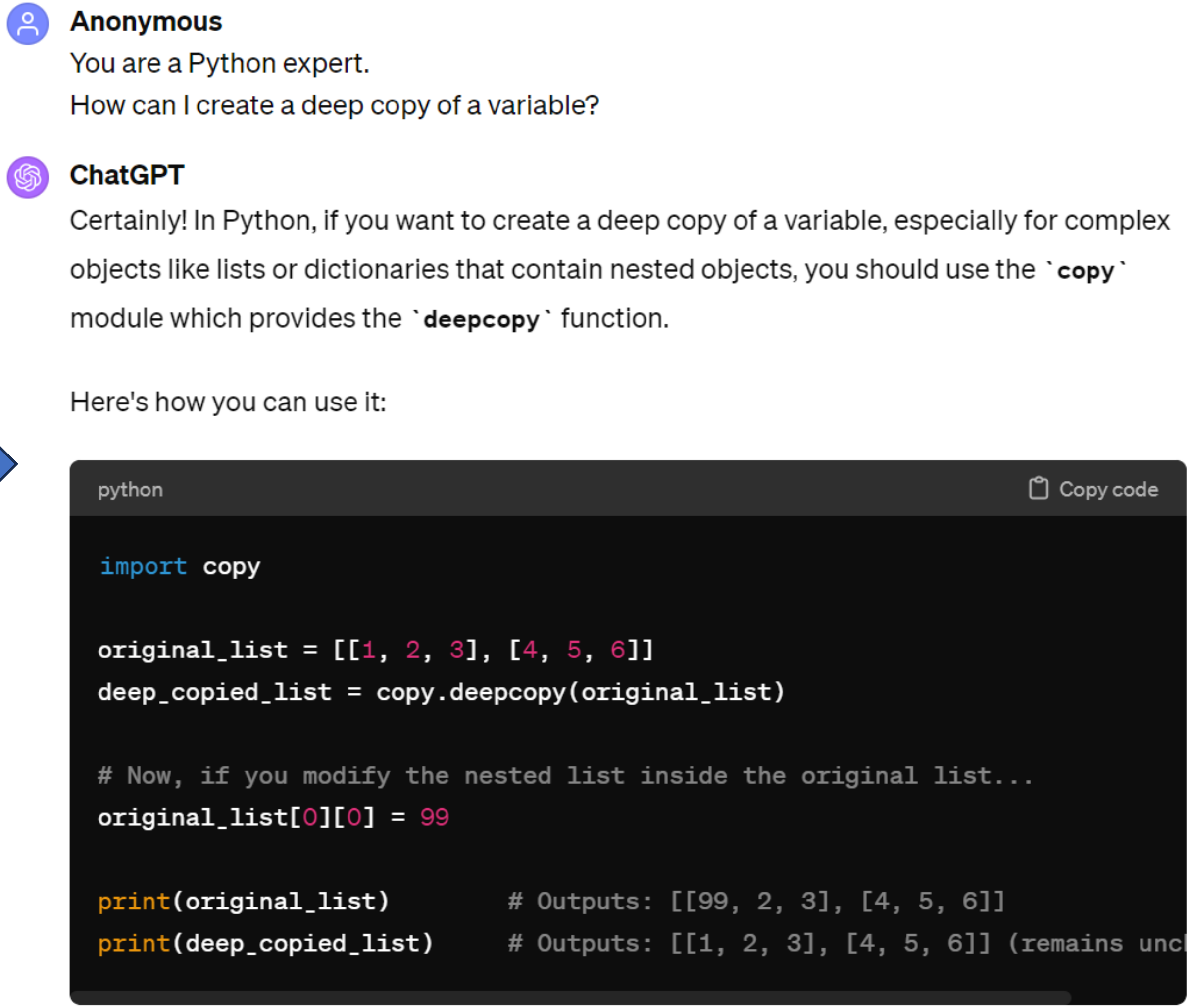


Anonymous

You are a Python expert.
How can I create a deep copy of a variable?

ChatGPT

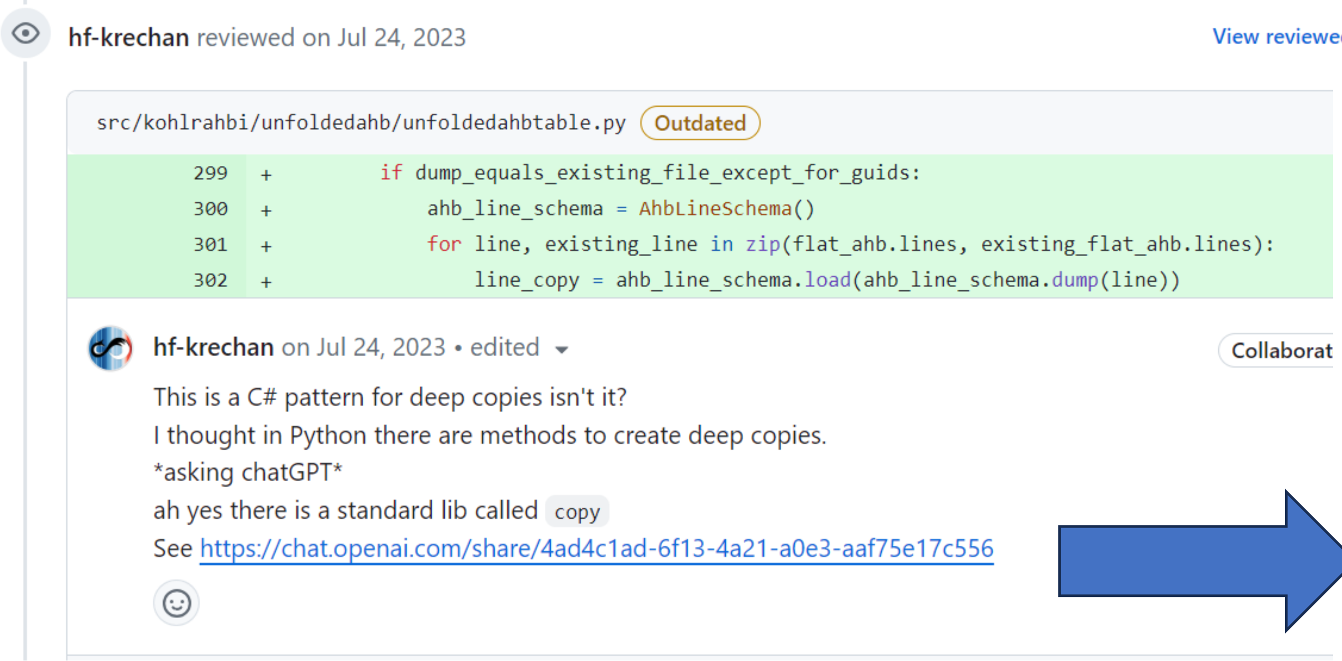
Certainly! In Python, if you want to create a deep copy of a variable, especially for complex objects like lists or dictionaries that contain nested objects, you should use the `copy` module which provides the `deepcopy` function.

Here's how you can use it:

```python
import copy

original_list = [[1, 2, 3], [4, 5, 6]]
deep_copied_list = copy.deepcopy(original_list)

# Now, if you modify the nested list inside the original list...
original_list[0][0] = 99

print(original_list)       # Outputs: [[99, 2, 3], [4, 5, 6]]
print(deep_copied_list)    # Outputs: [[1, 2, 3], [4, 5, 6]] (remains unc
```

[Xiao et al., MSR 2024]

How do developers interact with LLMs?



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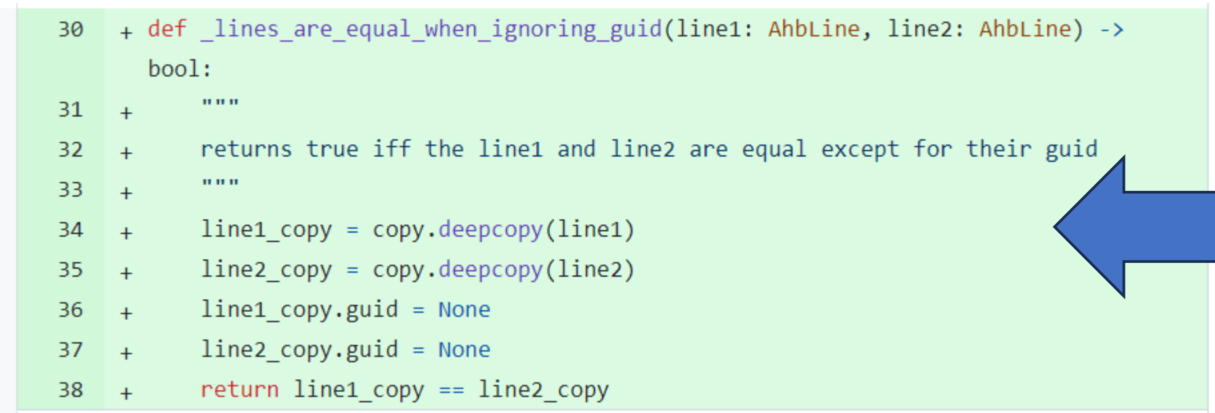
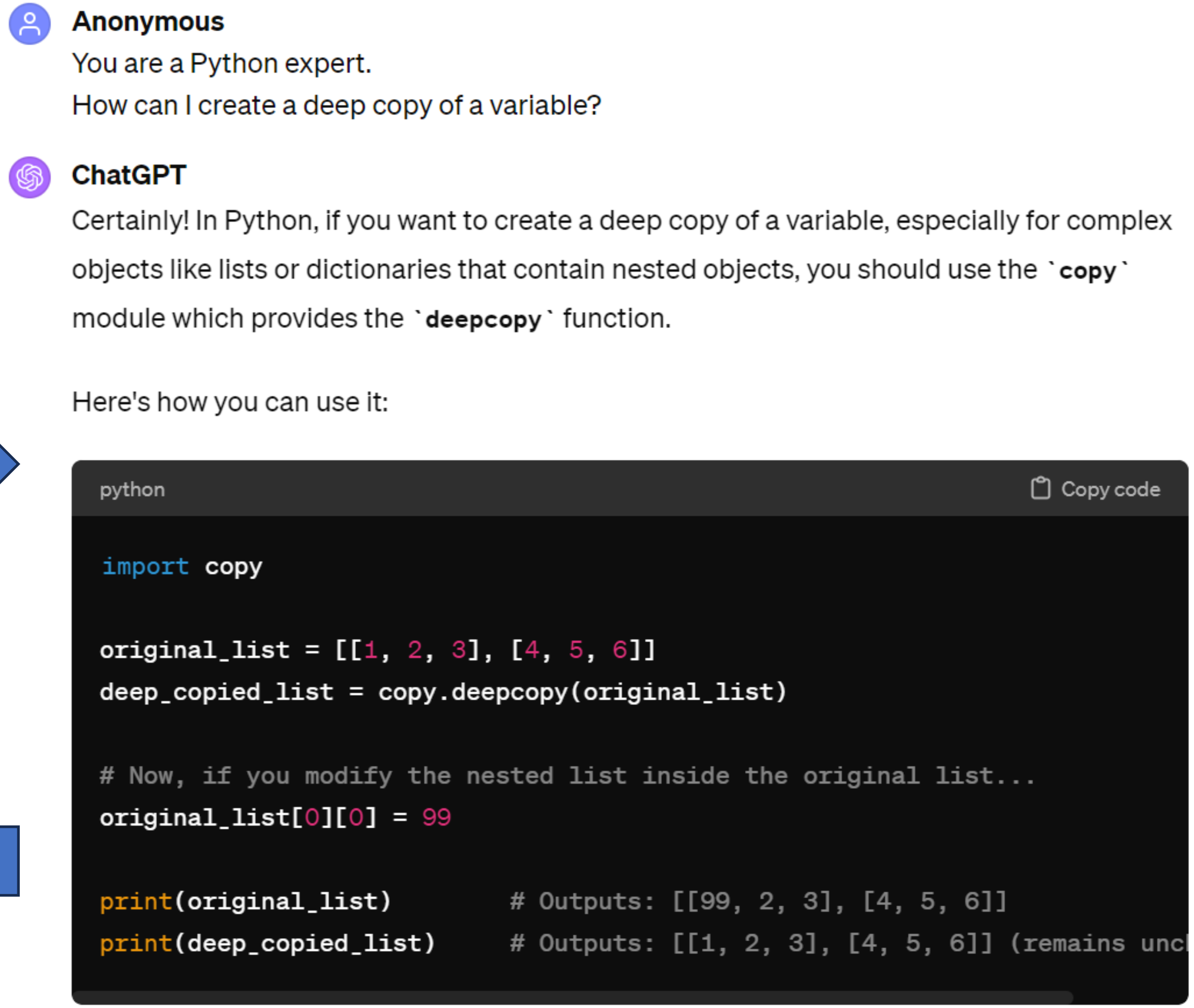


```
+ def _lines_are_equal_when_ignoring_guid(line1: AhbLine, line2: AhbLine) ->
  bool:
+     """
+     returns true iff the line1 and line2 are equal except for their guid
+     """
+     line1_copy = copy.deepcopy(line1)
+     line2_copy = copy.deepcopy(line2)
+     line1_copy.guid = None
+     line2_copy.guid = None
+     return line1_copy == line2_copy
```



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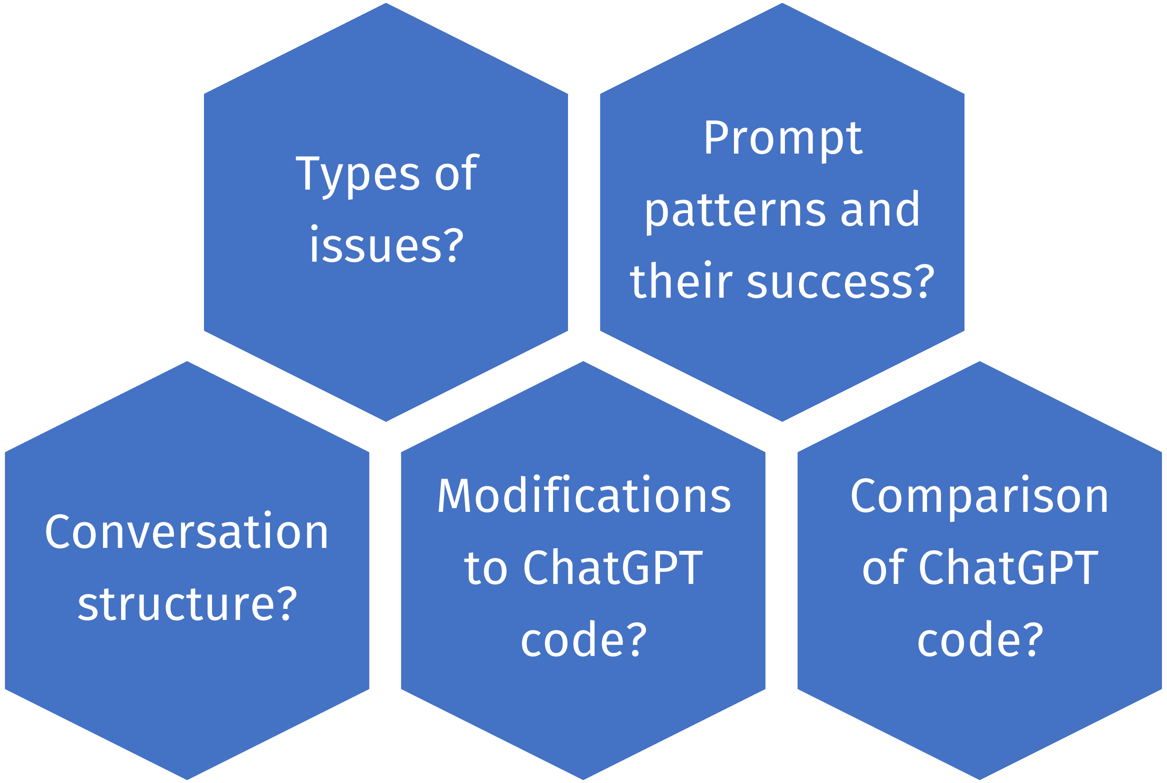
How do developers interact with LLMs?

Types of issues?

Prompt patterns and their success?

How do developers interact with LLMs?



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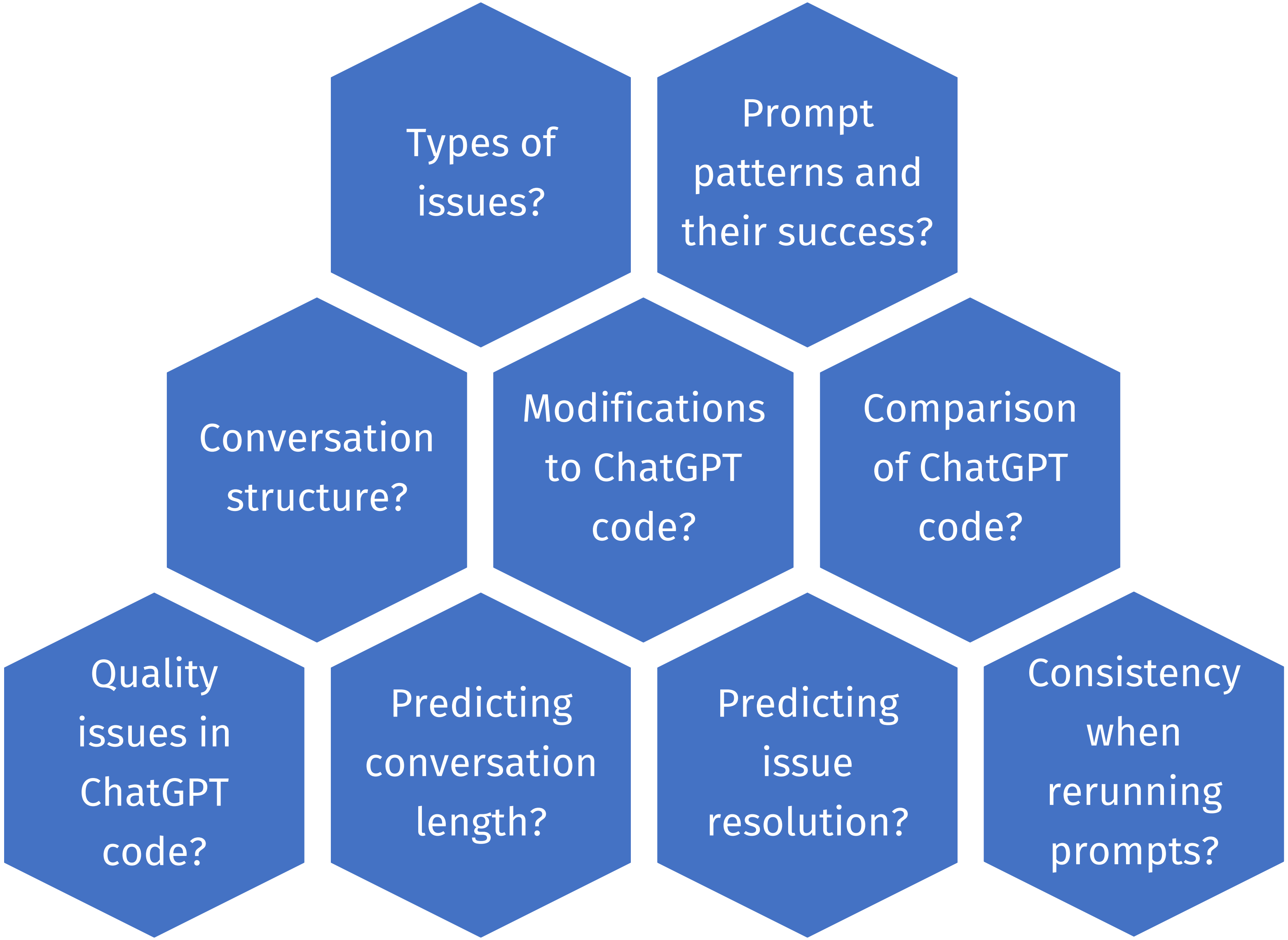
Conversation structure?

Modifications to ChatGPT code?

Comparison of ChatGPT code?

How do developers interact with LLMs?



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Conversation structure?

Modifications to ChatGPT code?

Comparison of ChatGPT code?

Quality issues in ChatGPT code?

Predicting conversation length?

Predicting issue resolution?

Consistency when rerunning prompts?

How do developers interact with LLMs?

Types of issues?

Prompt patterns an their su

Conversation structure?

Mod PT de?

Comparison of ChatGPT code?

Quality issue ChatGP code?

Predicting conversation length?

Predicting issue resolution?

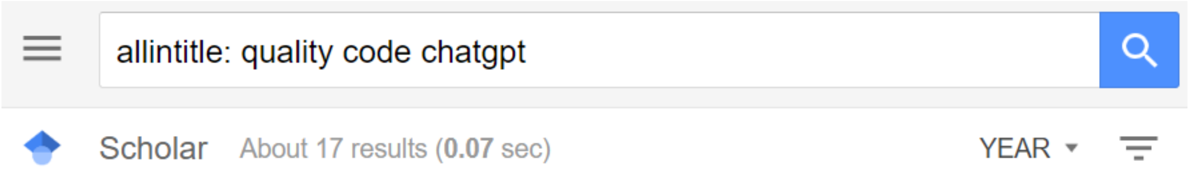
Consistency when rerunning prompts?

LLM interactions are data, too

Analyzing LLM output

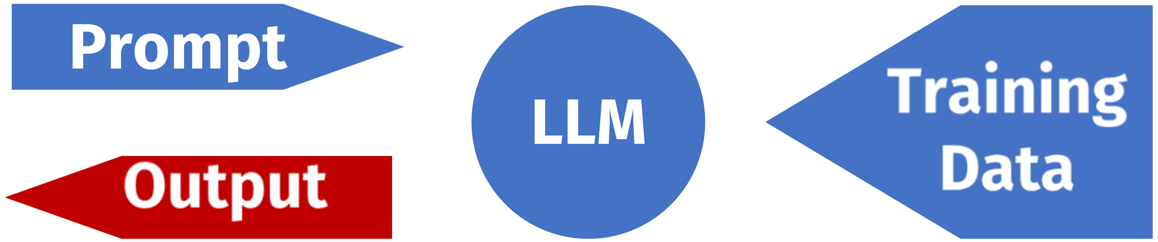
Prompt
Output
LLM
Training Data

Analyzing LLM output



allintitle: quality code chatgpt

Scholar About 17 results (**0.07** sec)



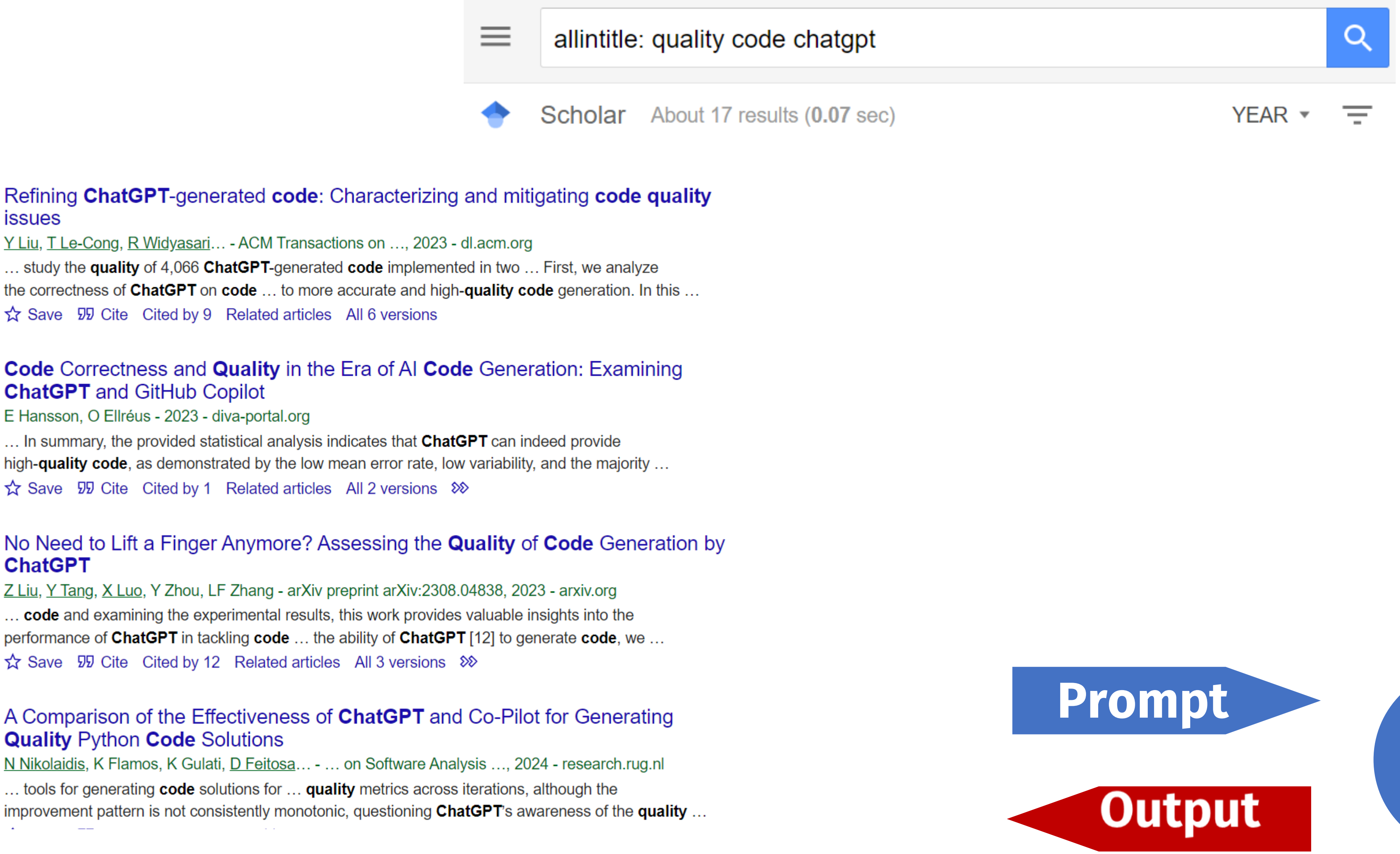
Prompt

Output

LLM

Training Data

Analyzing LLM output



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Y Liu, T Le-Cong, R Widyasari… - ACM Transactions on …, 2023 - dl.acm.org
… study the **quality** of 4,066 **ChatGPT**-generated **code** implemented in two … First, we analyze the correctness of **ChatGPT** on **code** … to more accurate and high-**quality code** generation. In this …
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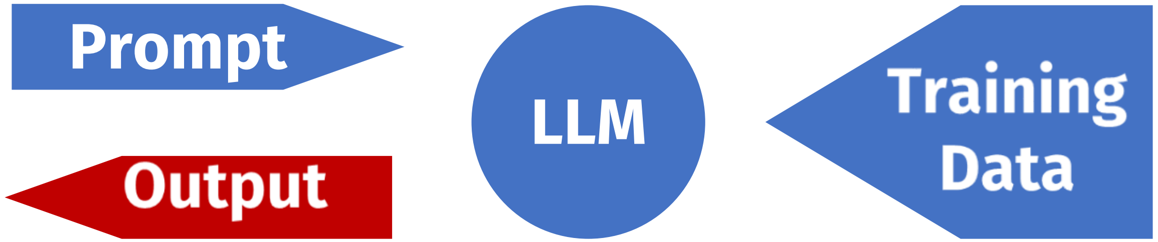
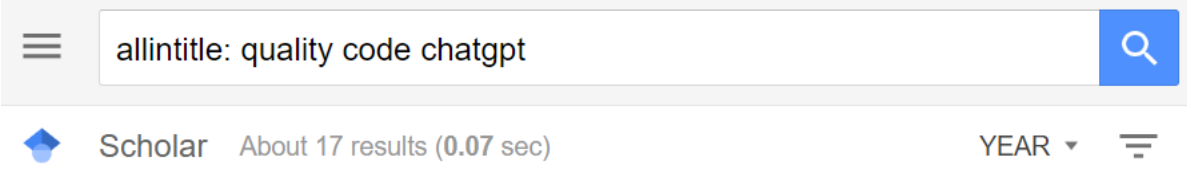


Analyzing LLM output



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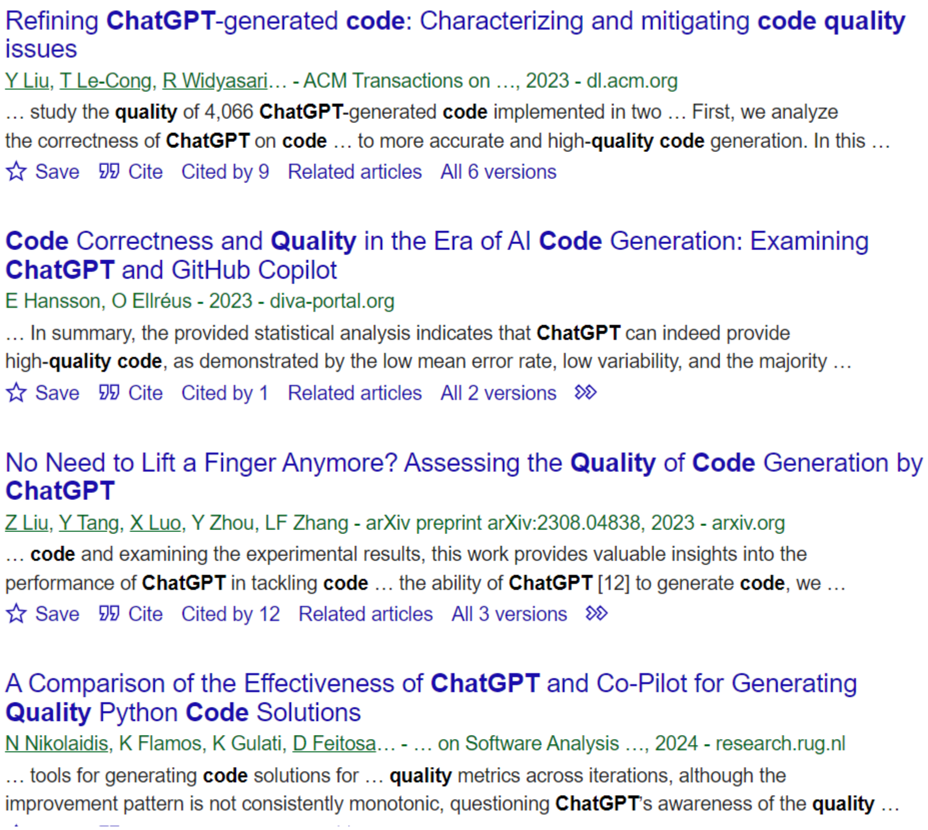

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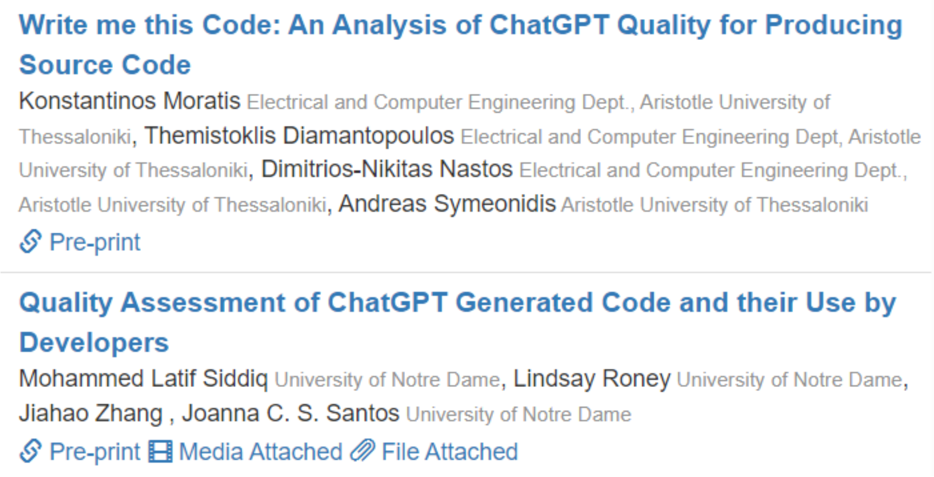
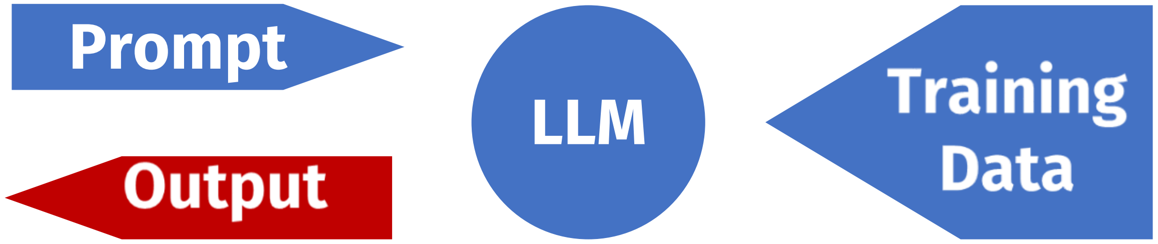


Write me this Code: An Analysis of ChatGPT Quality for Producing Source Code
Konstantinos Moratis Electrical and Computer Engineering Dept., Aristotle University of Thessaloniki, Themistoklis Diamantopoulos Electrical and Computer Engineering Dept, Aristotle University of Thessaloniki, Dimitrios-Nikitas Nastos Electrical and Computer Engineering Dept., Aristotle University of Thessaloniki, Andreas Symeonidis Aristotle University of Thessaloniki

Quality Assessment of ChatGPT Generated Code and their Use by Developers
Mohammed Latif Siddiq University of Notre Dame, Lindsay Roney University of Notre Dame, Jiahao Zhang , Joanna C. S. Santos University of Notre Dame



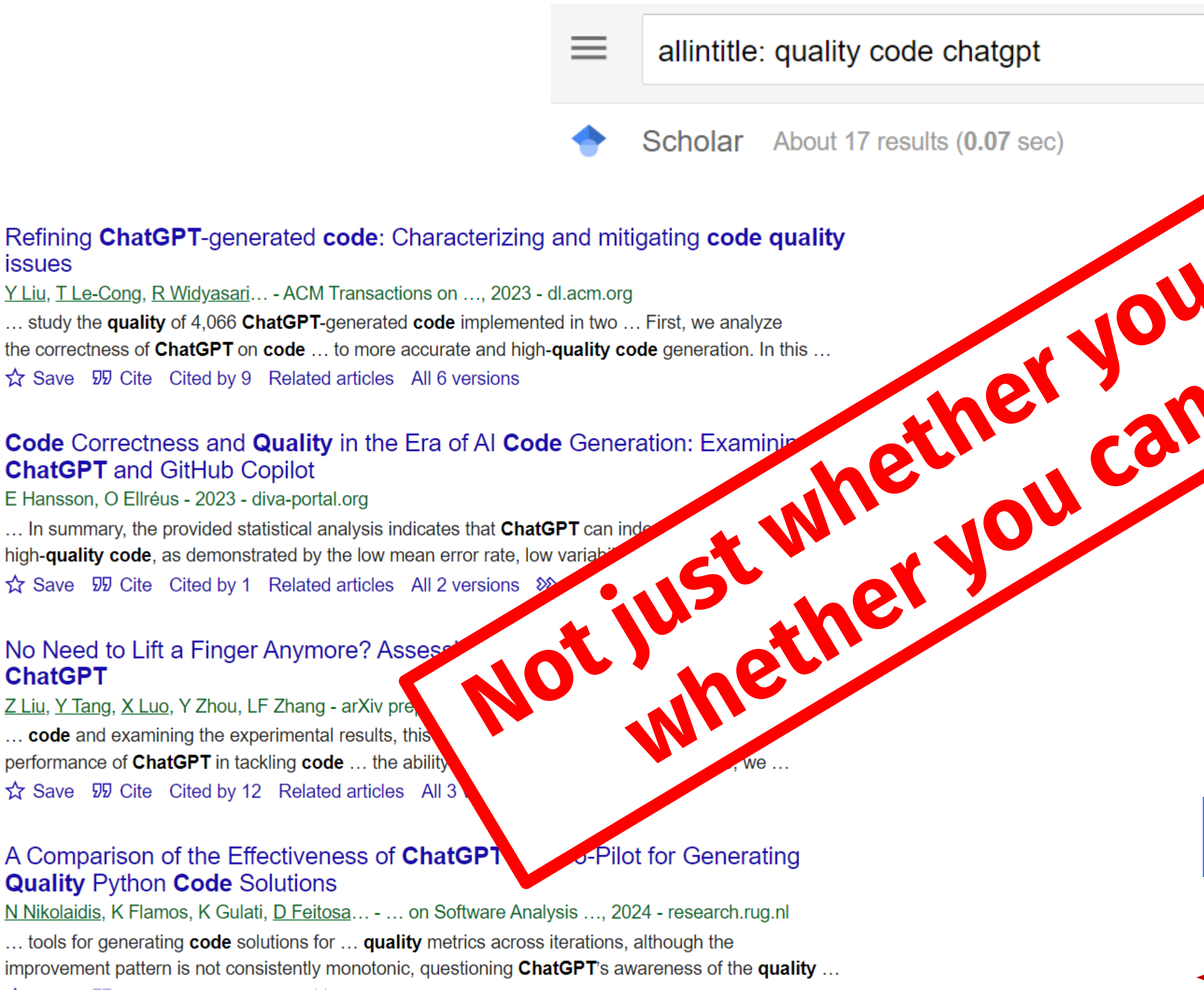
Prompt

Output

LLM

Training Data

Analyzing LLM output



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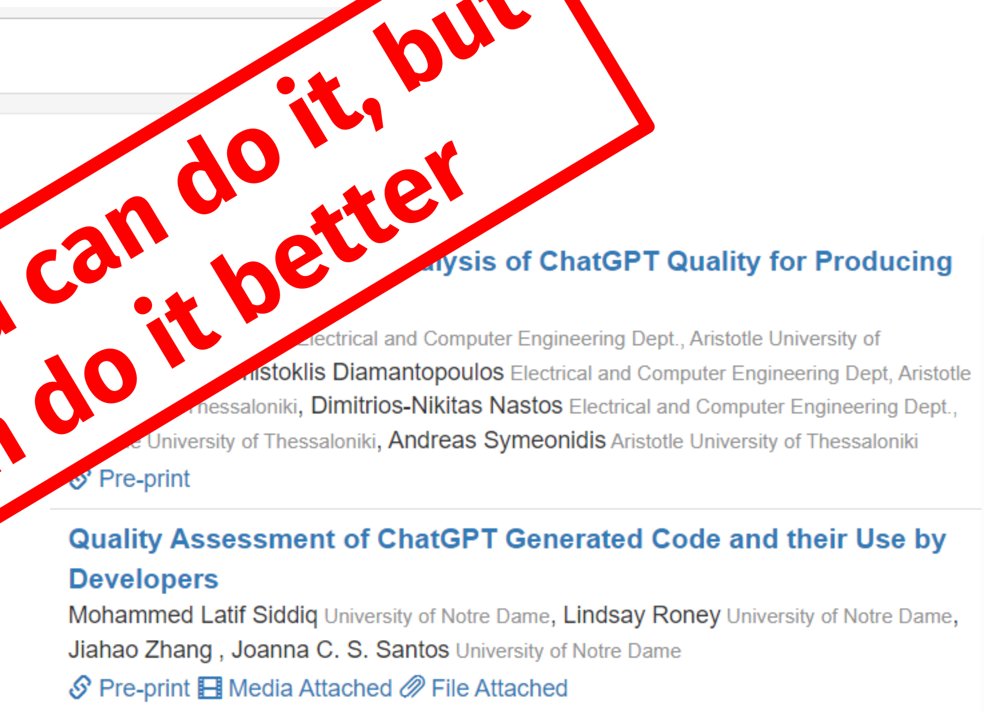

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istoklis Diamantopoulos Electrical and Computer Engineering Dept, Aristotle
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Pre-print

Quality Assessment of ChatGPT Generated Code and their Use by Developers
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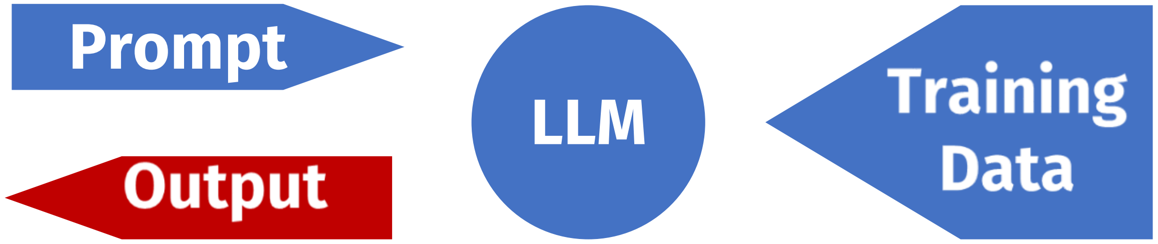
Pre-print Media Attached File Attached

Not just whether you can do it, but whether you can do it better



Analyzing LLM output

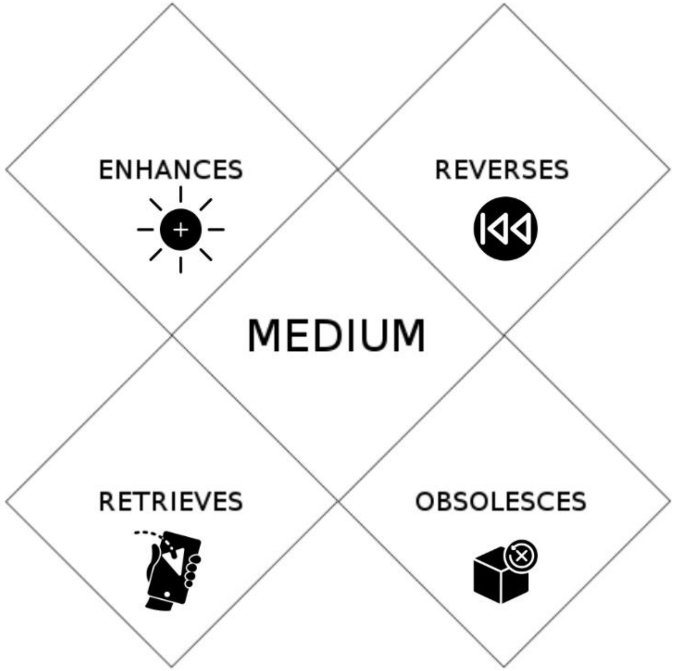
Prompt

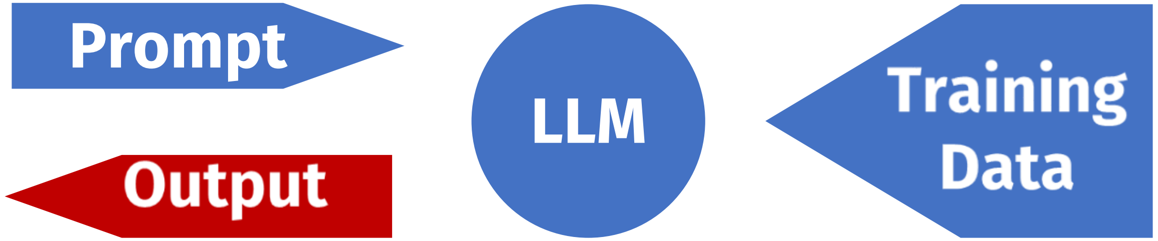
Output

LLM

Training Data

Analyzing LLM output




Prompt

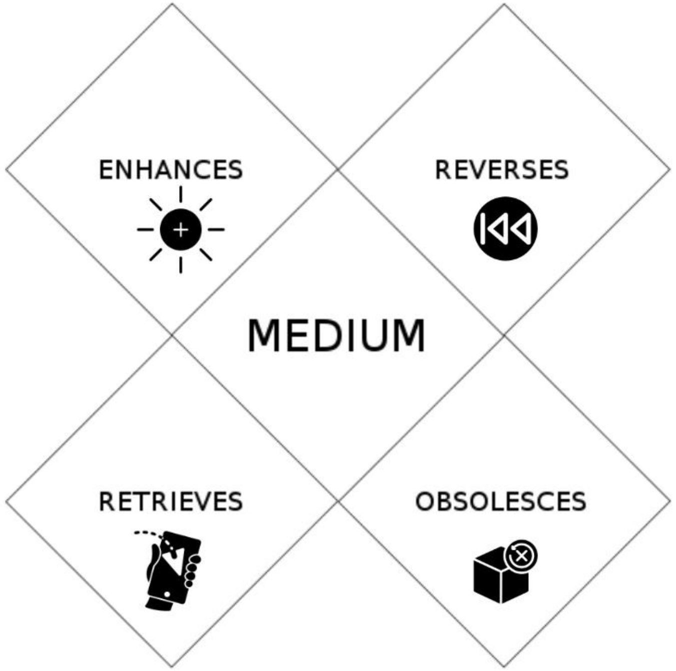
Output

LLM

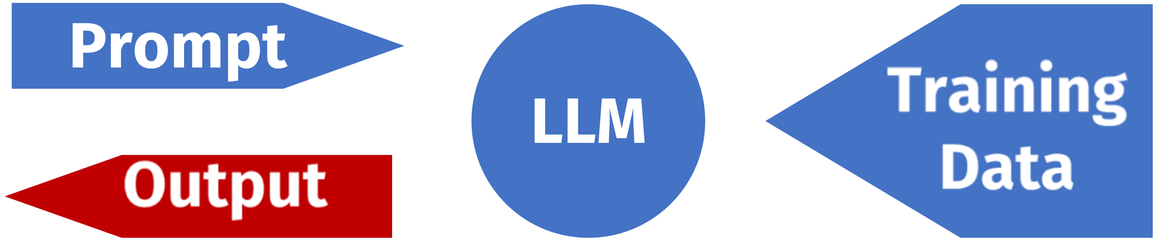
Training Data

[Storey et al., 2024]

Analyzing LLM output

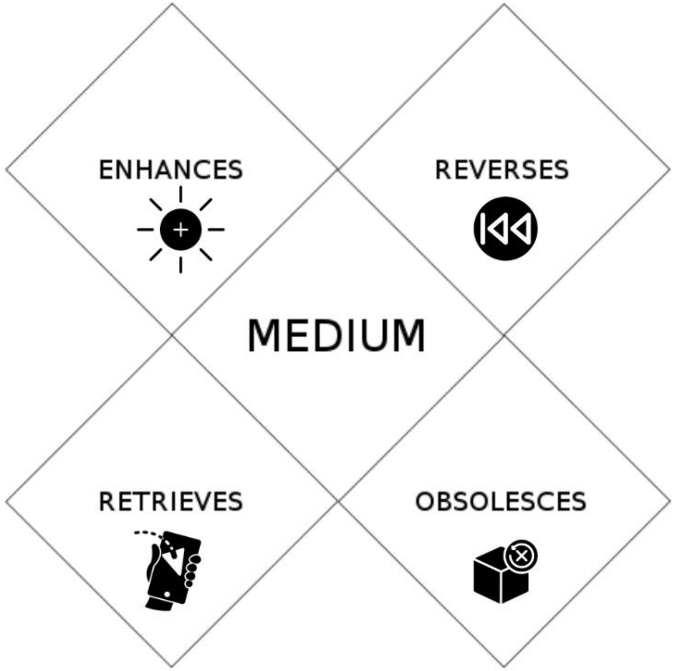


What does the technology
... enhance or amplify?
... make obsolete?
... retrieve that had been obsolesced earlier?
... reverse or flip into when pushed to extremes?



[Storey et al., 2024]

Analyzing LLM output



What do we lose from past solutions now rendered obsolete by this technology?

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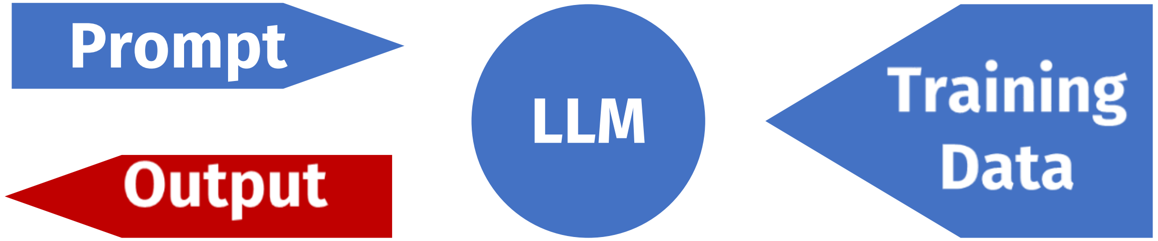
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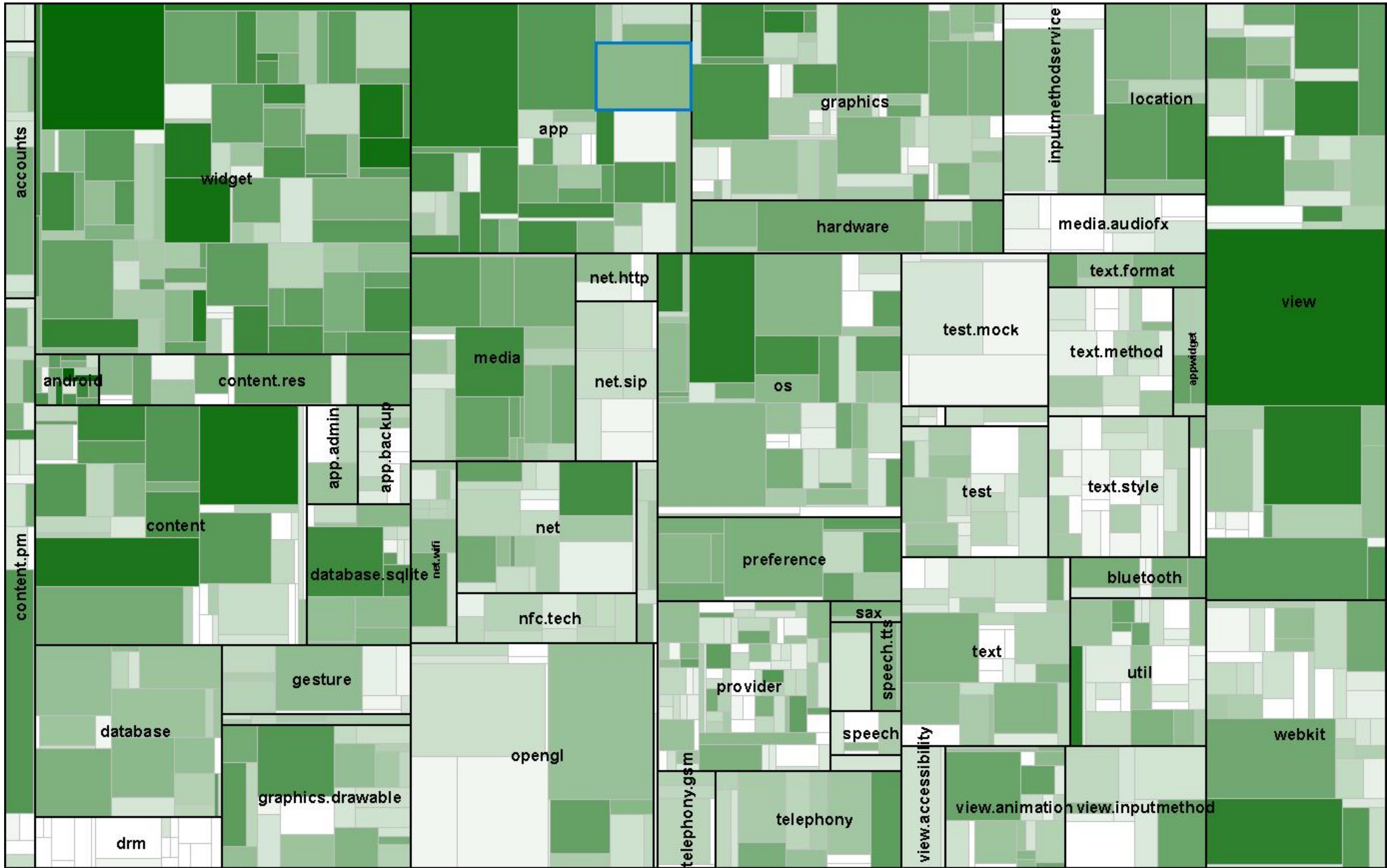
Output

LLM

Training Data

[Storey et al., 2024]

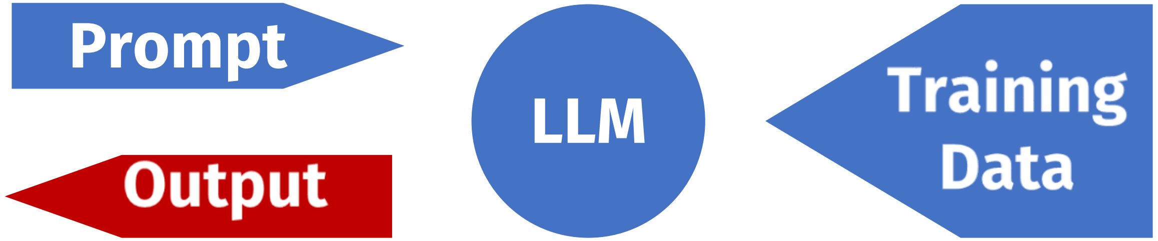
Stack Overflow replaces API documentation



[Parnin et al., 2012]

Analyzing LLM output

What do we lose from past solutions now rendered obsolete by this technology?



Analyzing LLM output

What do we lose from past solutions now rendered obsolete by this technology?

What human nuances are lost in **code** generated by LLMs?

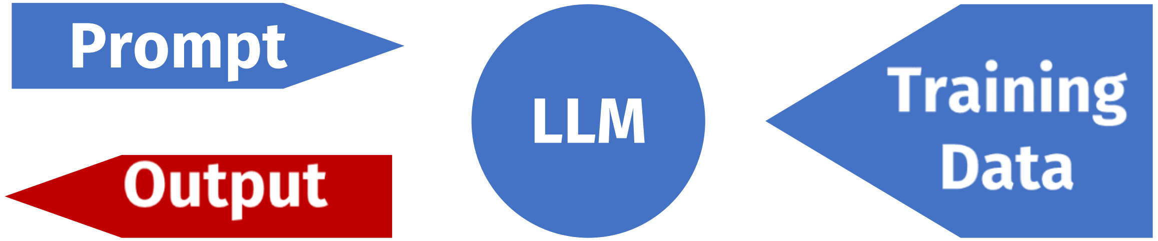
What do we miss from traditional **bug reports** with LLM error identification?

What collaborative and mentorship elements are lost with LLM **code reviews**?

What human insights are lost in **commit** documentation when handled by LLMs?

What human intuition is overlooked in LLM-generated **tests**?

What community aspects are lost when LLMs answer on **Stack Overflow**?



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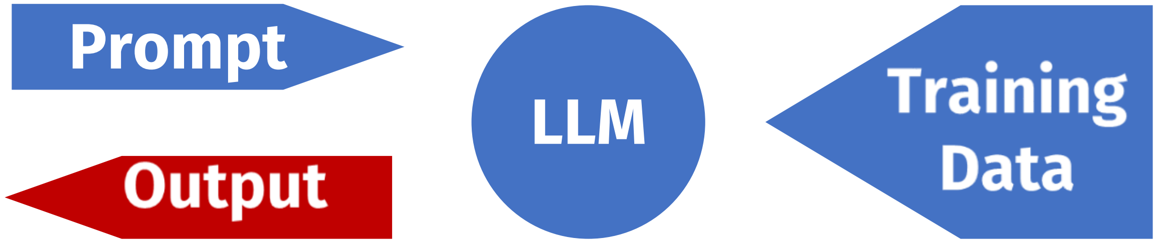
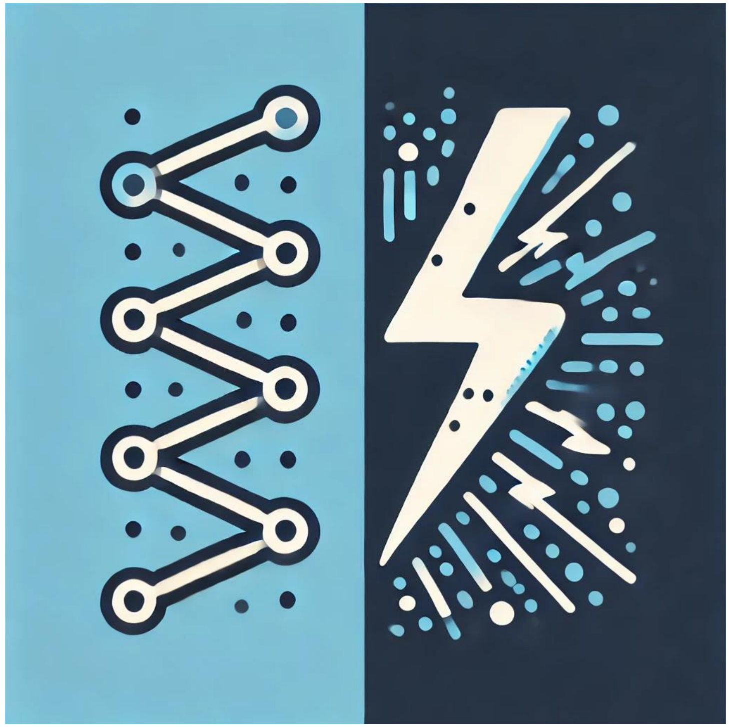
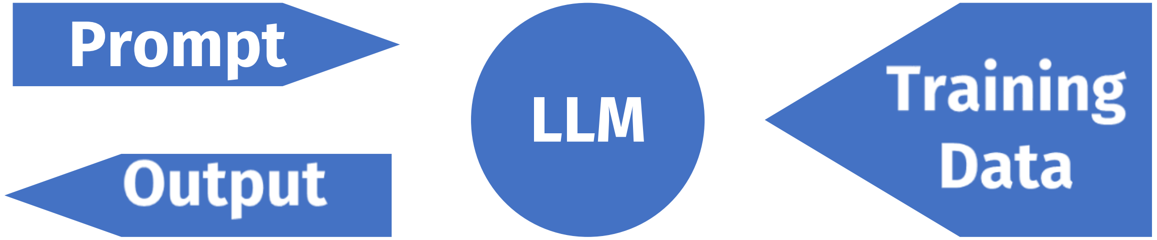
What community aspects hen LLMs answer on **Stack Overflow**?

LLM output beyond quality



EMSE Research in the Age of LLMs





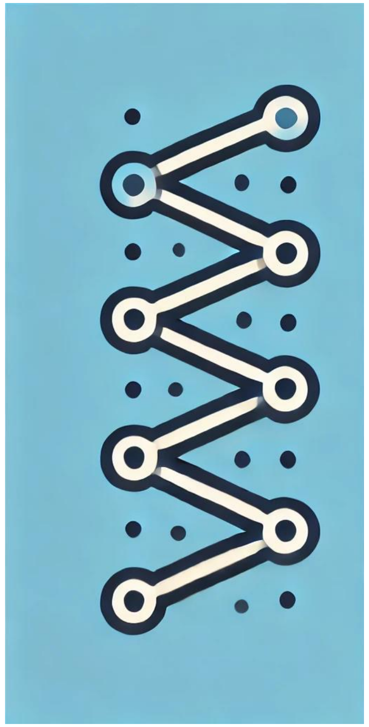
Prompt

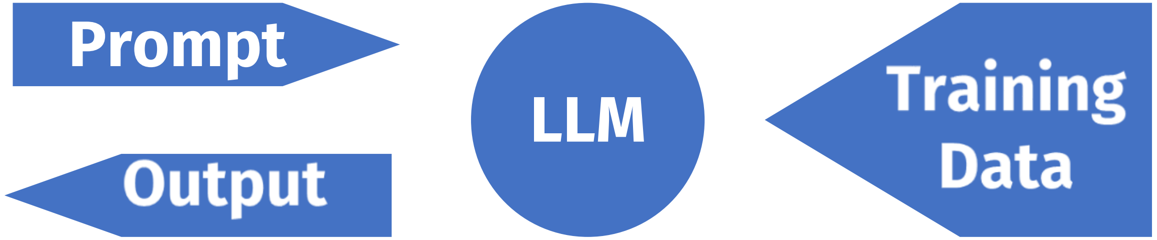
Output

LLM

Training Data

EMSE Research in the Age of LLMs





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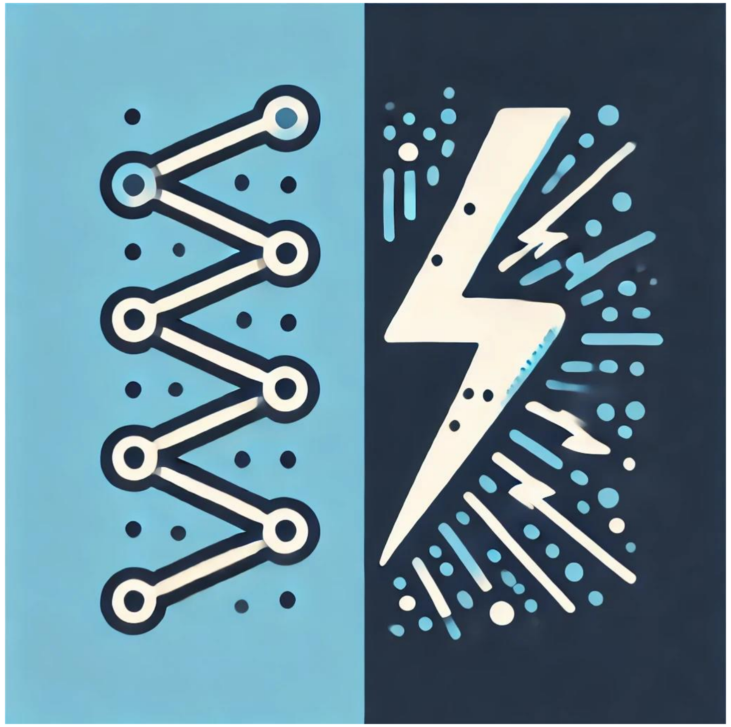
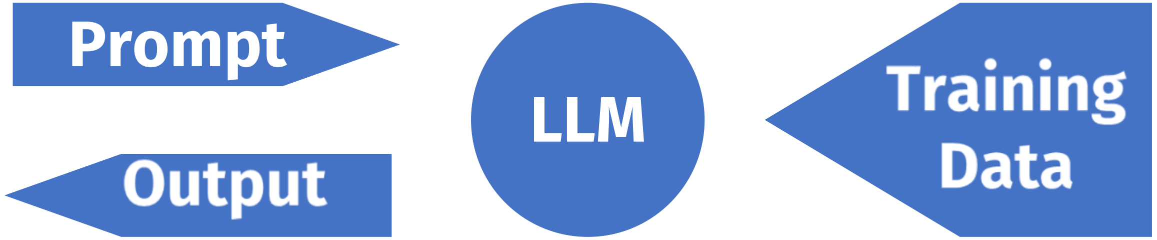




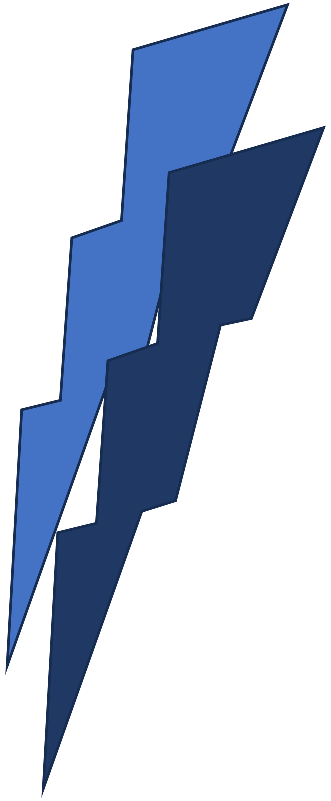
Prompt

Output

LLM

Training Data

Disruption



Disruption

Phenomena

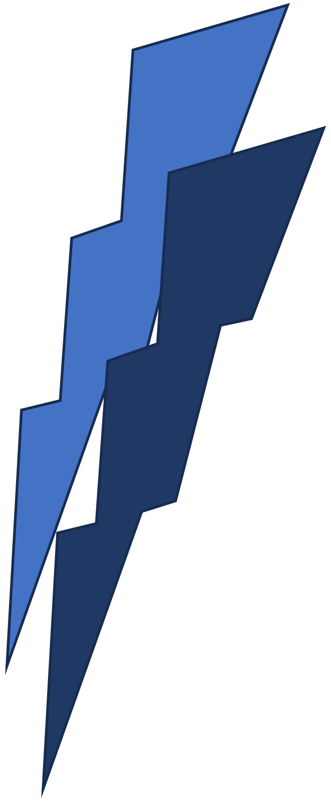
Methods

Theories

Threats

Ethics

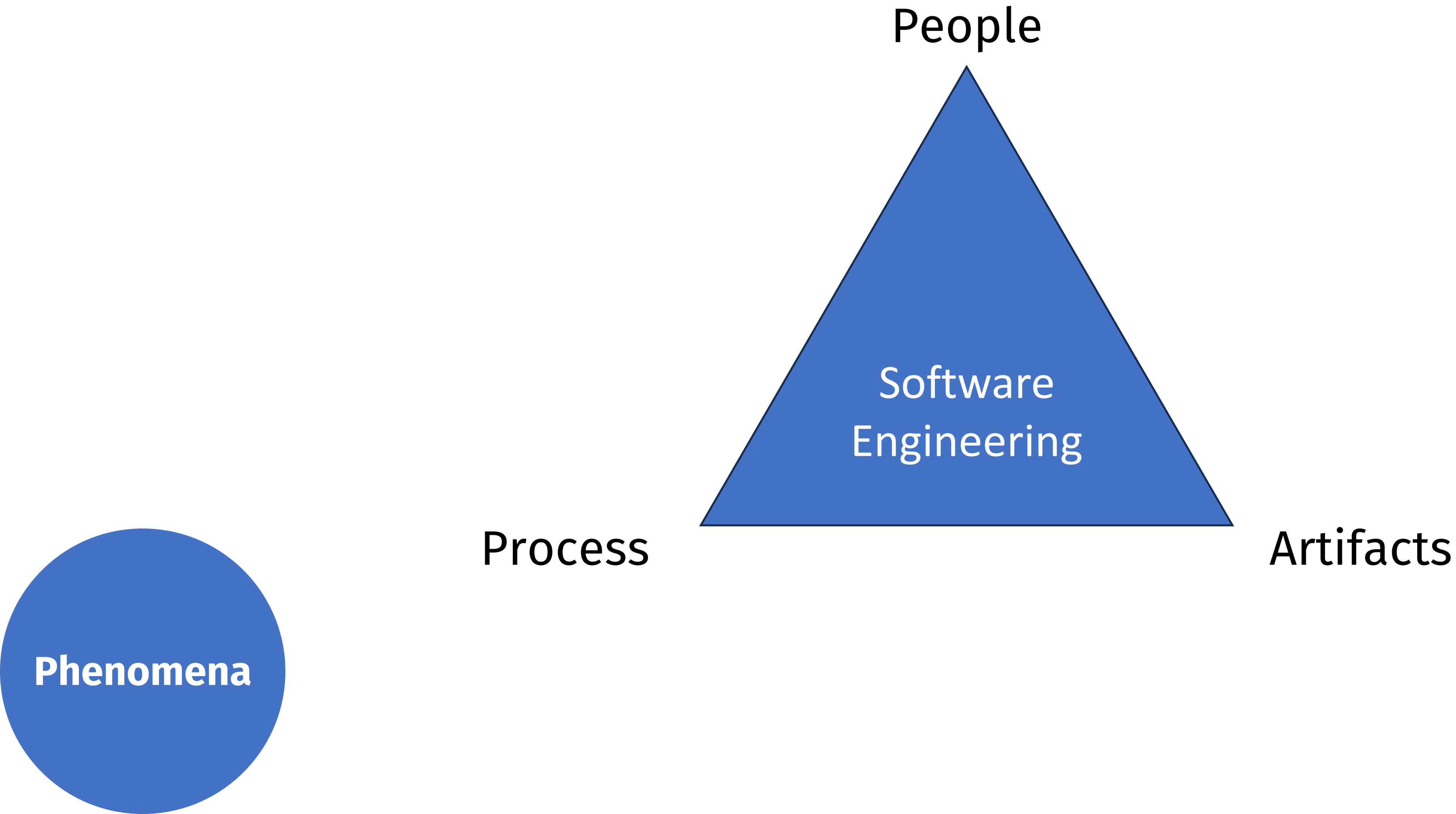
Tool



Disruption

Phenomena

Challenges existing definitions



People

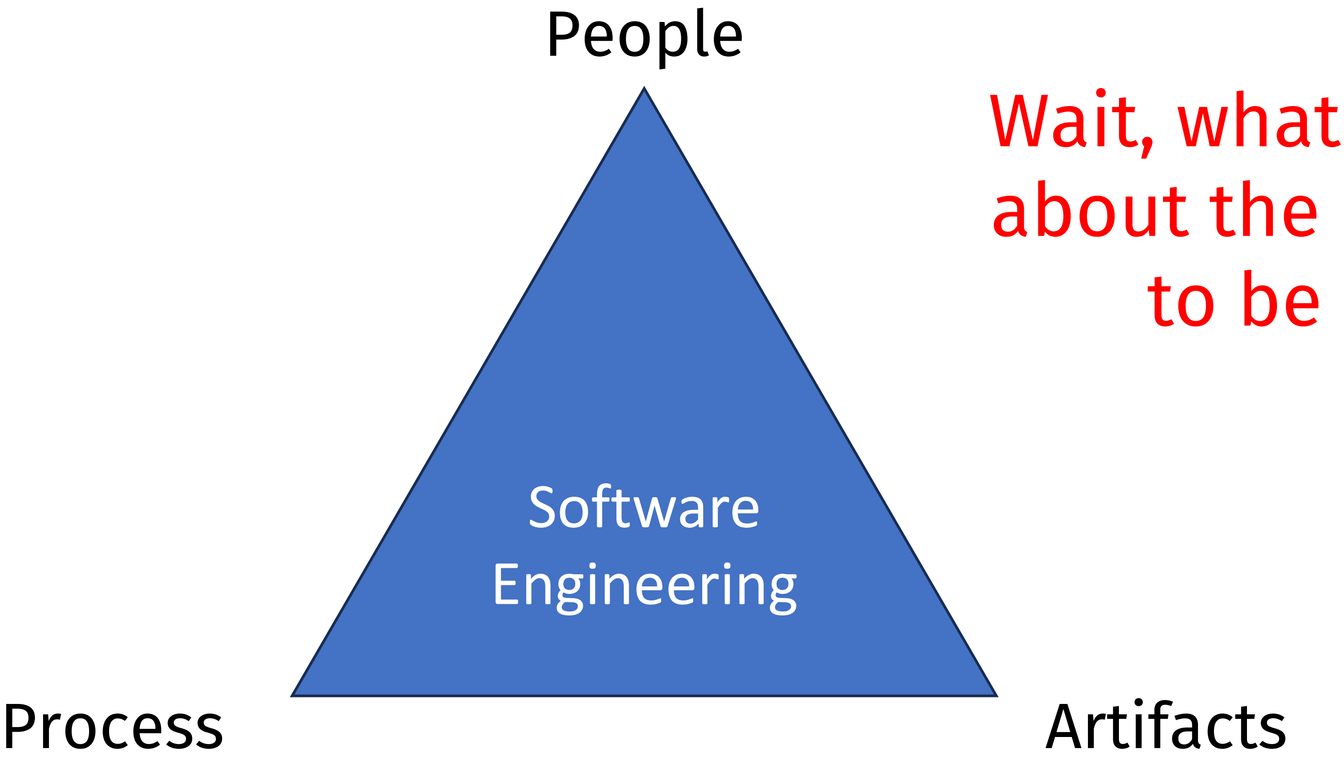
Software Engineering

Process

Artifacts

Phenomena

Challenges existing definitions



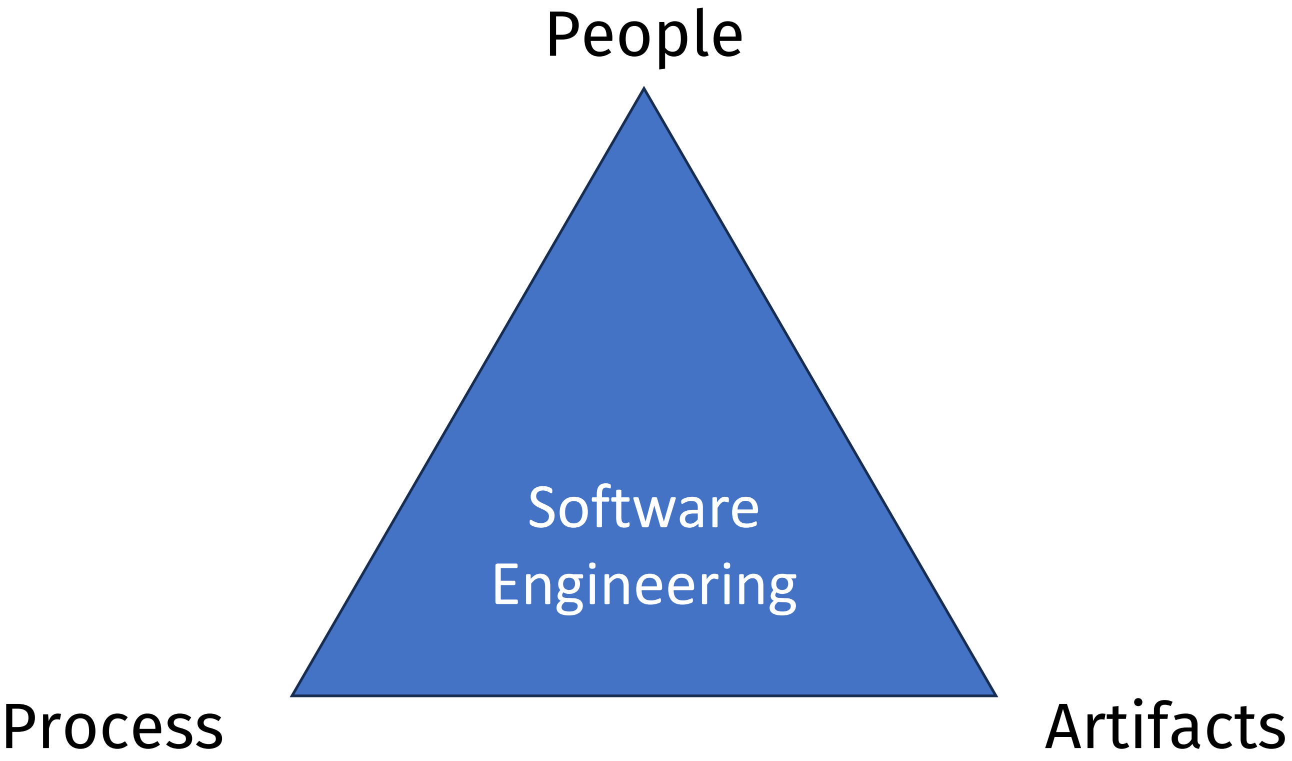
Wait, what do you know about the **phenomenon** to be studied?

Phenomena

Disruption

Methods

Mixed methods & interdisciplinary work



People

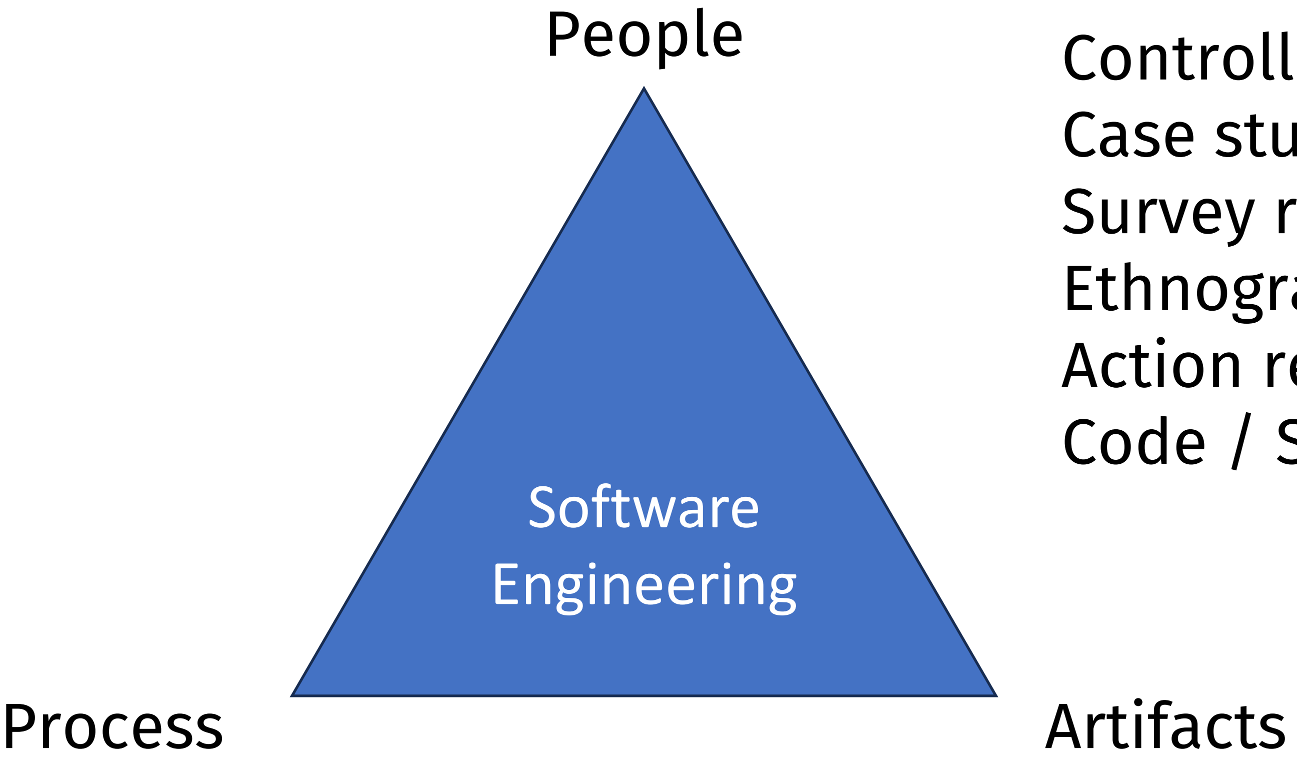
Software Engineering

Process

Artifacts

Methods

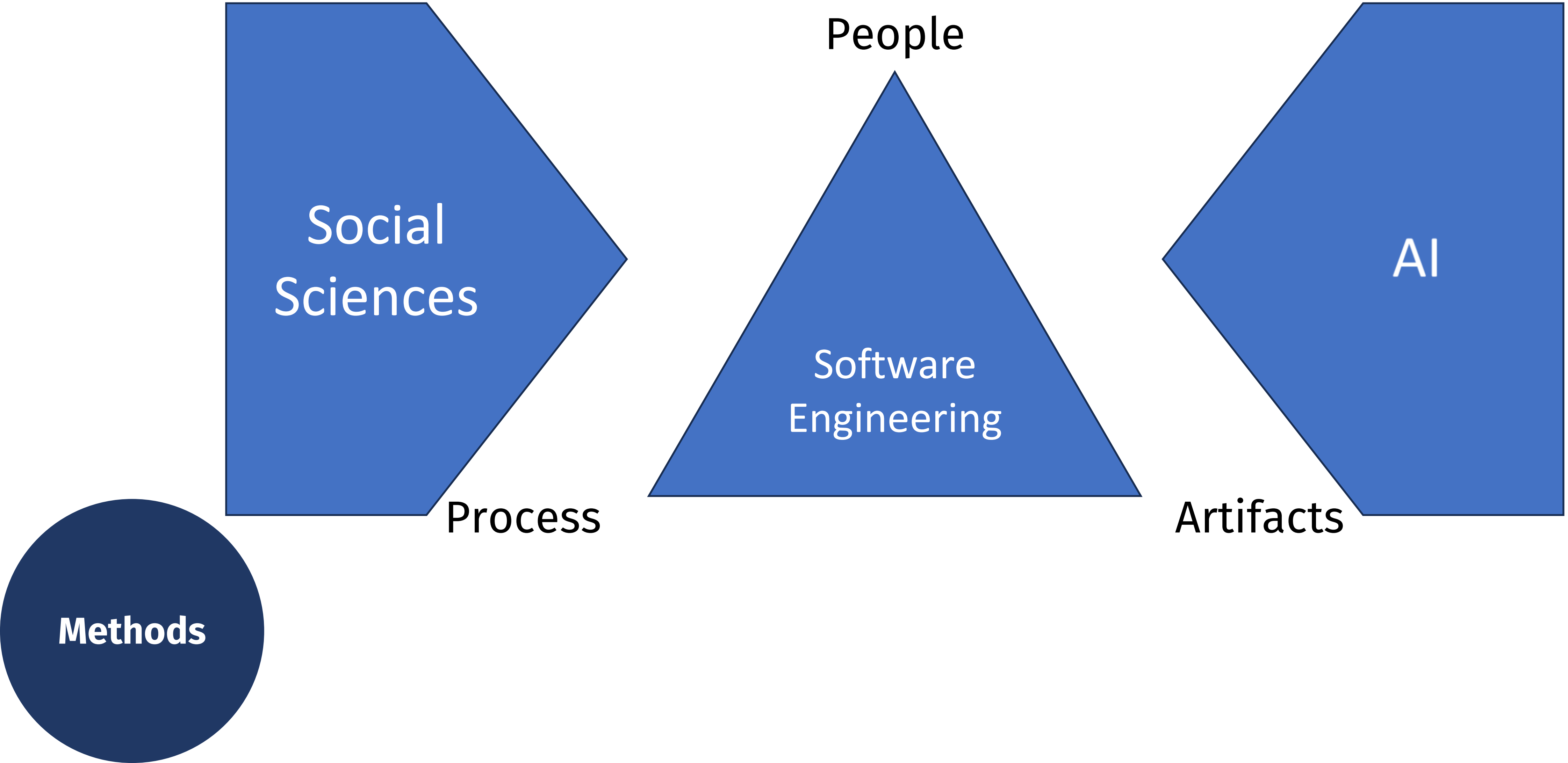
Mixed methods & interdisciplinary work



Controlled experiments
Case studies
Survey research
Ethnographies
Action research
Code / System analyses

Methods

Mixed methods & interdisciplinary work


Social Sciences

People

Software Engineering

Process

Artifacts

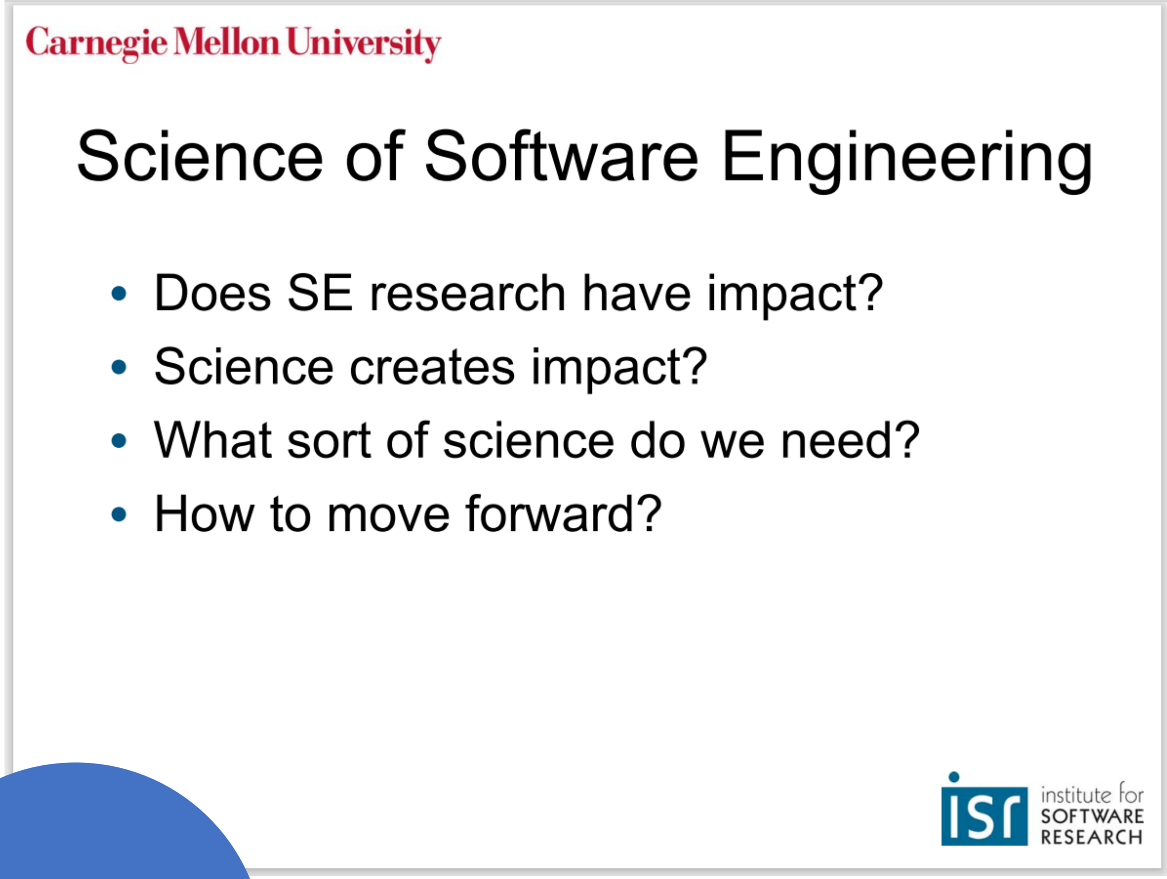
AI

Methods

Disruption

Theories

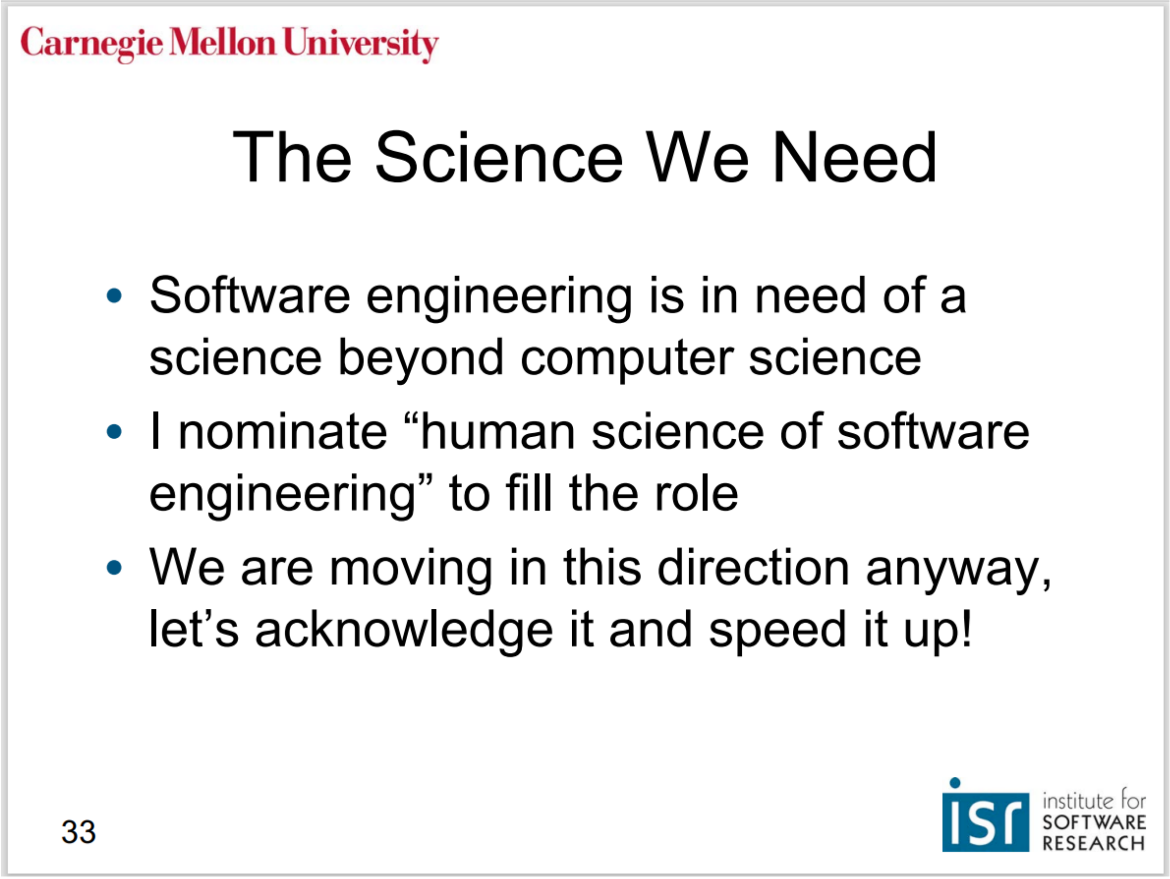
Understand and frame LLMs’ impact



Carnegie Mellon University

Science of Software Engineering

- Does SE research have impact?
- Science creates impact?
- What sort of science do we need?
- How to move forward?



Carnegie Mellon University

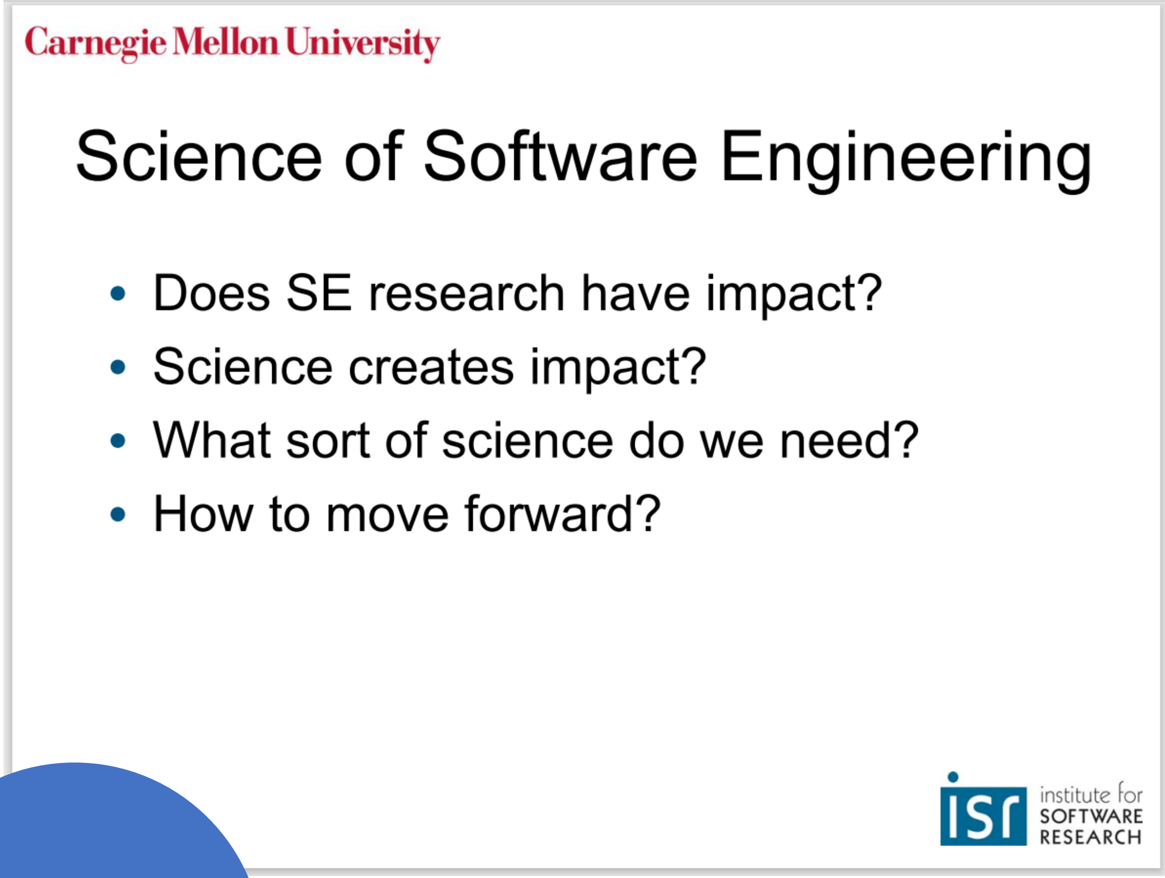
The Science We Need

- Software engineering is in need of a science beyond computer science
- I nominate “human science of software engineering” to fill the role
- We are moving in this direction anyway, let’s acknowledge it and speed it up!

33

Theories

Understand and frame LLMs' impact



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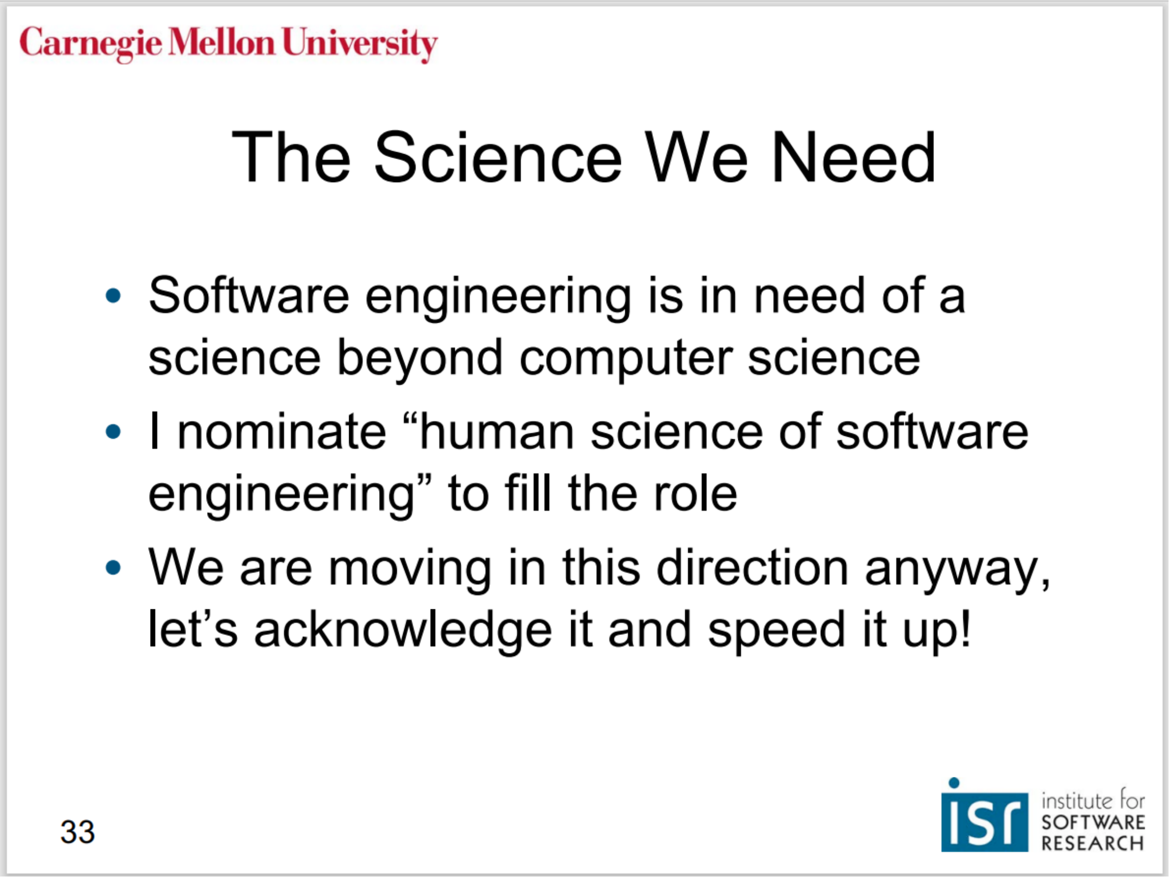

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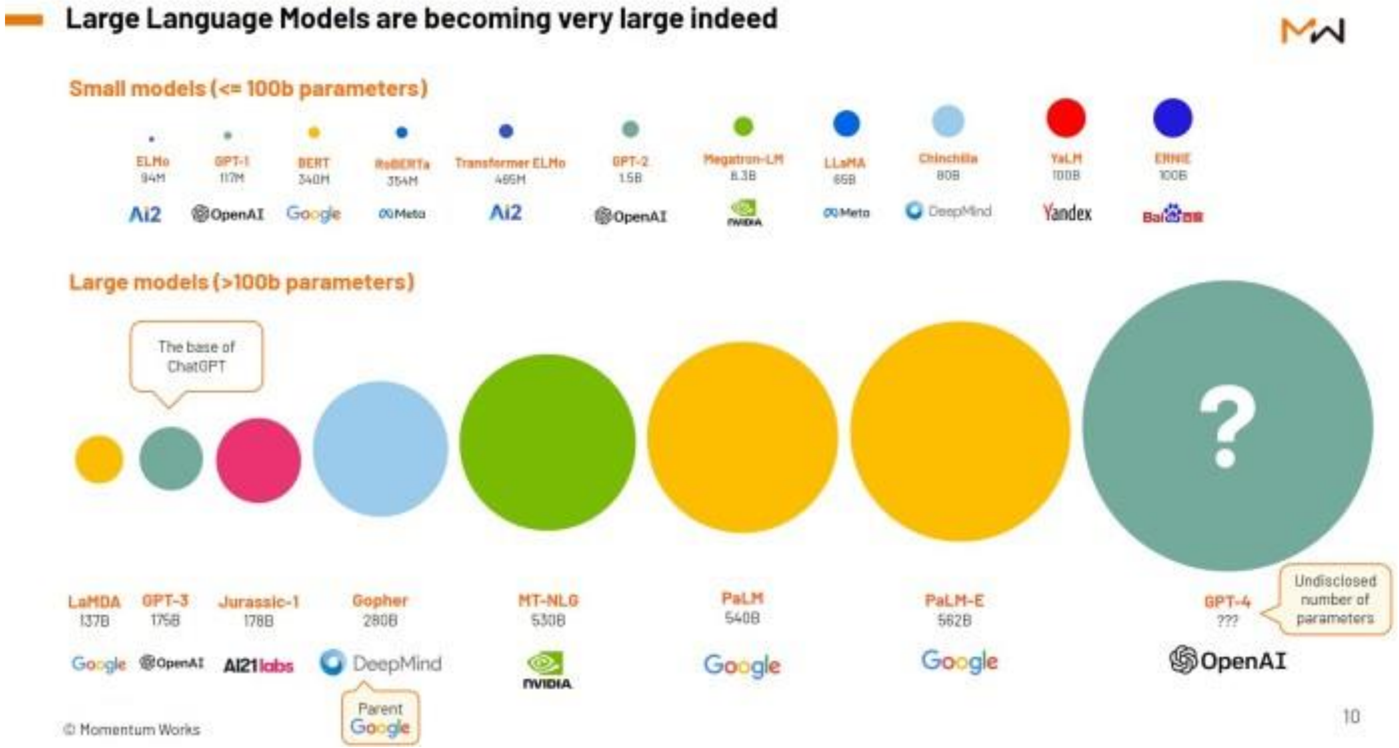
Theories

Disruption

Threats

Non-deterministic and rapidly evolving



https://thelowdown.momentum.asia/the-emergence-of-large-language-models-llms/

Threats

Disruption

Ethics

Evolving legal and ethical frameworks

AI systems should respect human rights, diversity, and the autonomy of individuals.

Ethics

Evolving legal and ethical frameworks

AI systems should respect human rights, diversity, and the autonomy of individuals.

Documenting Ethical Considerations in Open Source AI Models

Haoyu Gao
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Mansooreh Zahedi
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2024

ABSTRACT

Background: The development of AI-enabled software heavily depends on AI model documentation, such as model cards, due to

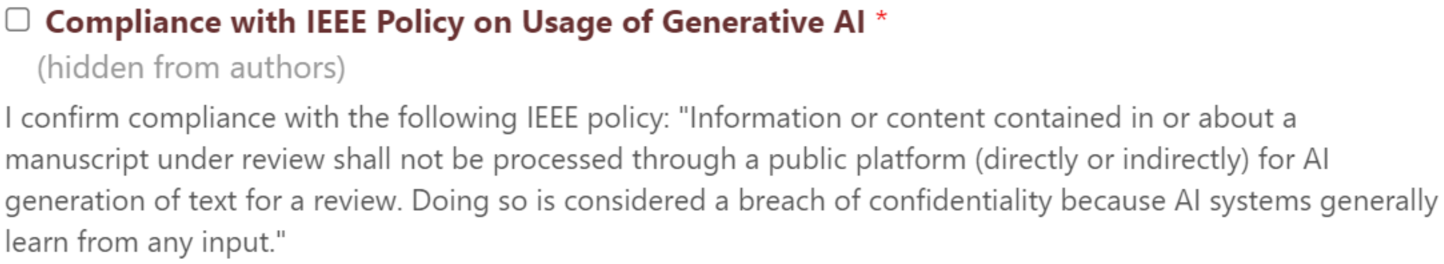
Models. In *Proceedings of 18th International Symposium on Empirical Software Engineering and Measurement (ESEM '24)*. ACM, New York, NY, USA, 12 pages. https://doi.org/XXXXXXX.XXXXXXX

Ethics

Disruption

Tool

AI-assisted SE research



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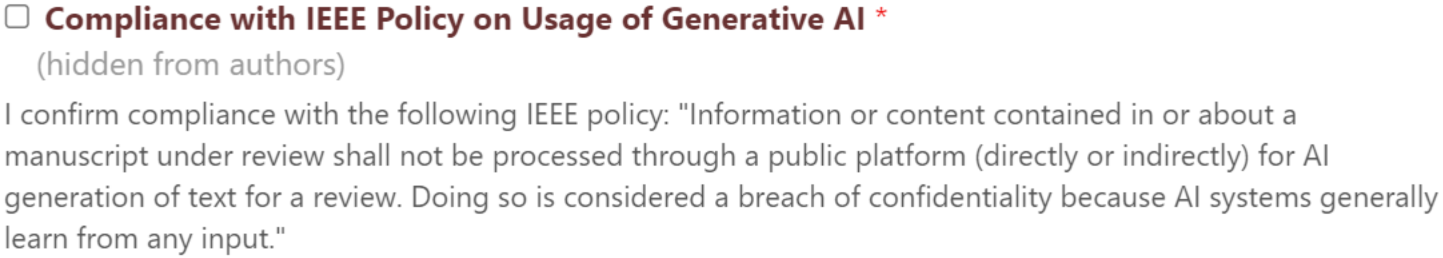
Tool

AI-assisted SE research



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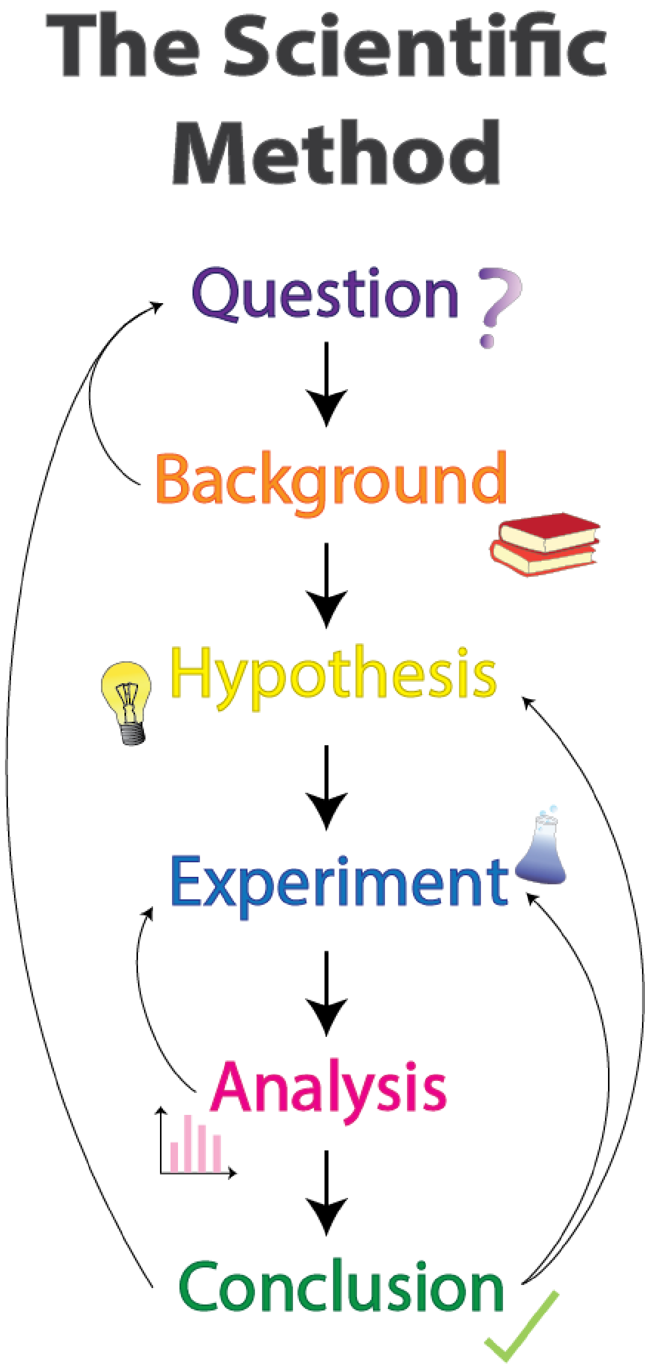


The Scientific Method

Question

Background

Hypothesis

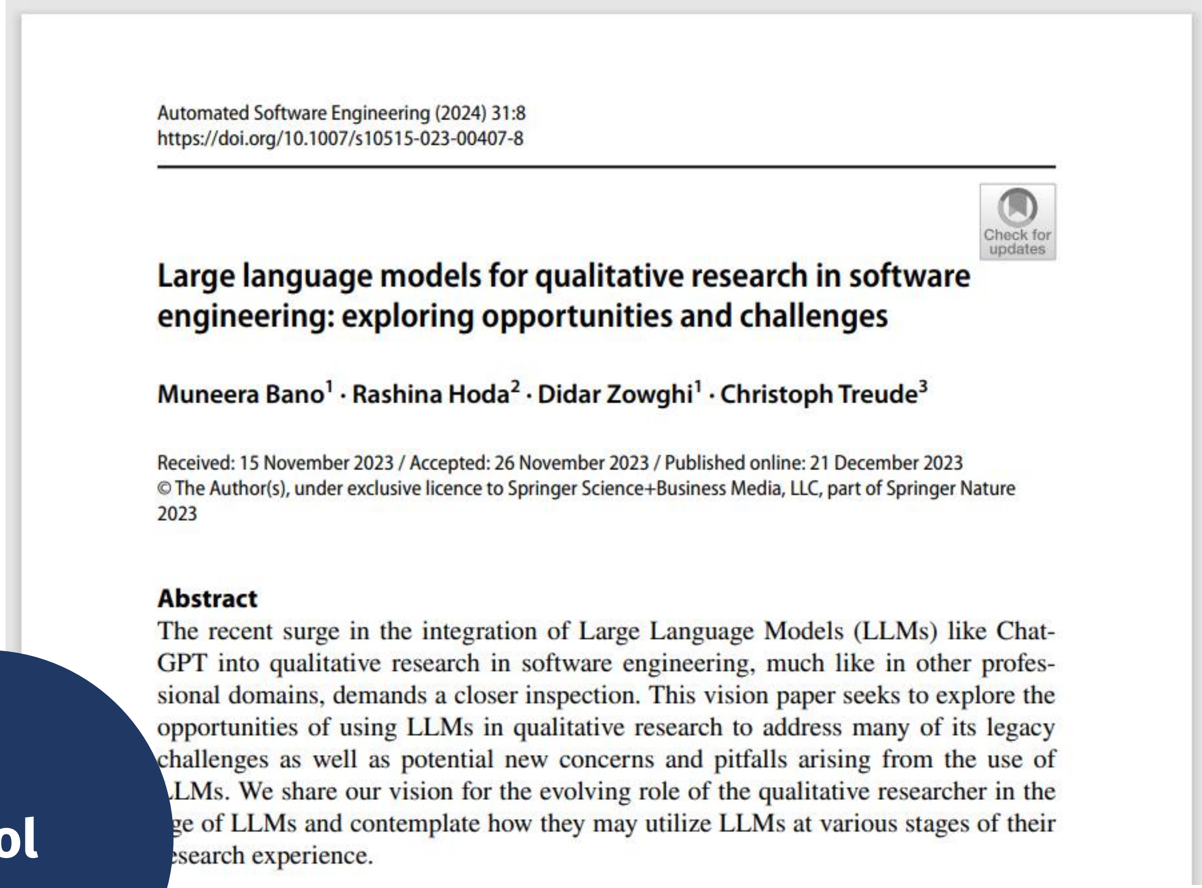
Experiment

Analysis

Conclusion

https://study.com/learn/lesson/scientific-method-example-steps.html

AI-assisted SE research



Automated Software Engineering (2024) 31:8
https://doi.org/10.1007/s10515-023-00407-8

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Large language models for qualitative research in software engineering: exploring opportunities and challenges

Muneera Bano[1] · Rashina Hoda[2] · Didar Zowghi[1] · Christoph Treude[3]

Received: 15 November 2023 / Accepted: 26 November 2023 / Published online: 21 December 2023
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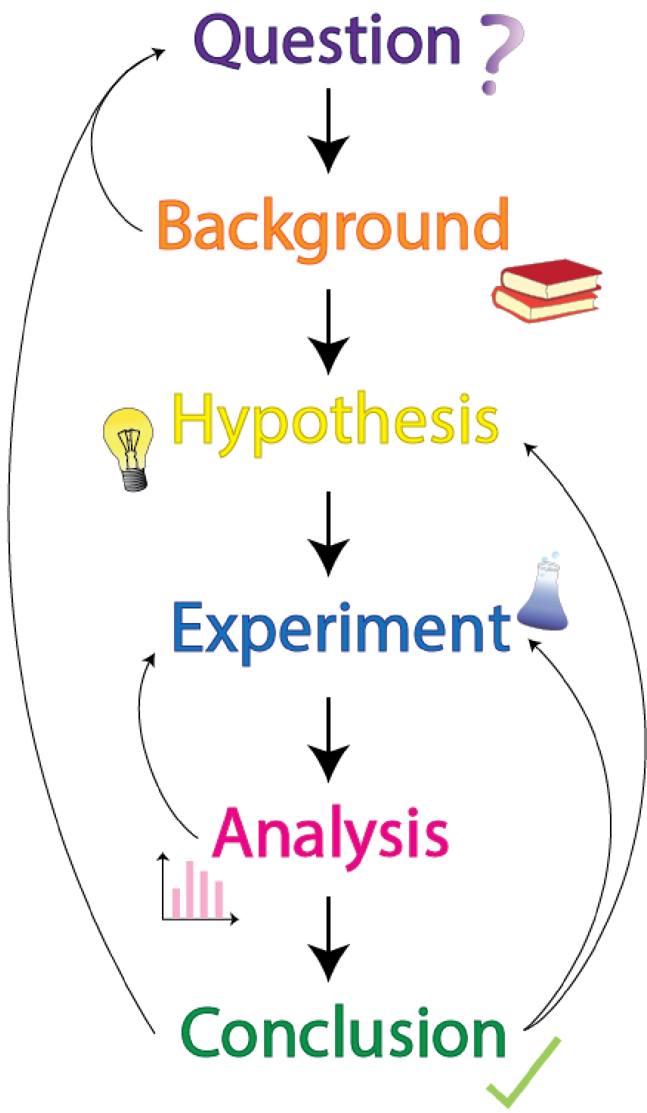
Abstract
The recent surge in the integration of Large Language Models (LLMs) like ChatGPT into qualitative research in software engineering, much like in other professional domains, demands a closer inspection. This vision paper seeks to explore the opportunities of using LLMs in qualitative research to address many of its legacy challenges as well as potential new concerns and pitfalls arising from the use of LMs. We share our vision for the evolving role of the qualitative researcher in the ge of LLMs and contemplate how they may utilize LLMs at various stages of their esearch experience.

Tool

The Scientific Method



Question

Background

Hypothesis

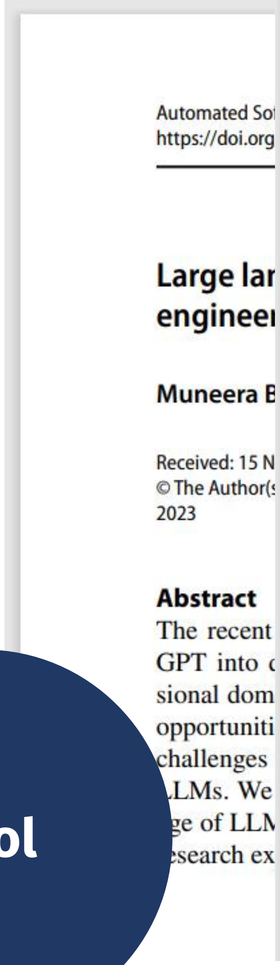
Experiment

Analysis

Conclusion

https://study.com/learn/lesson/scientific-method-example-steps.html

AI-assisted SE research



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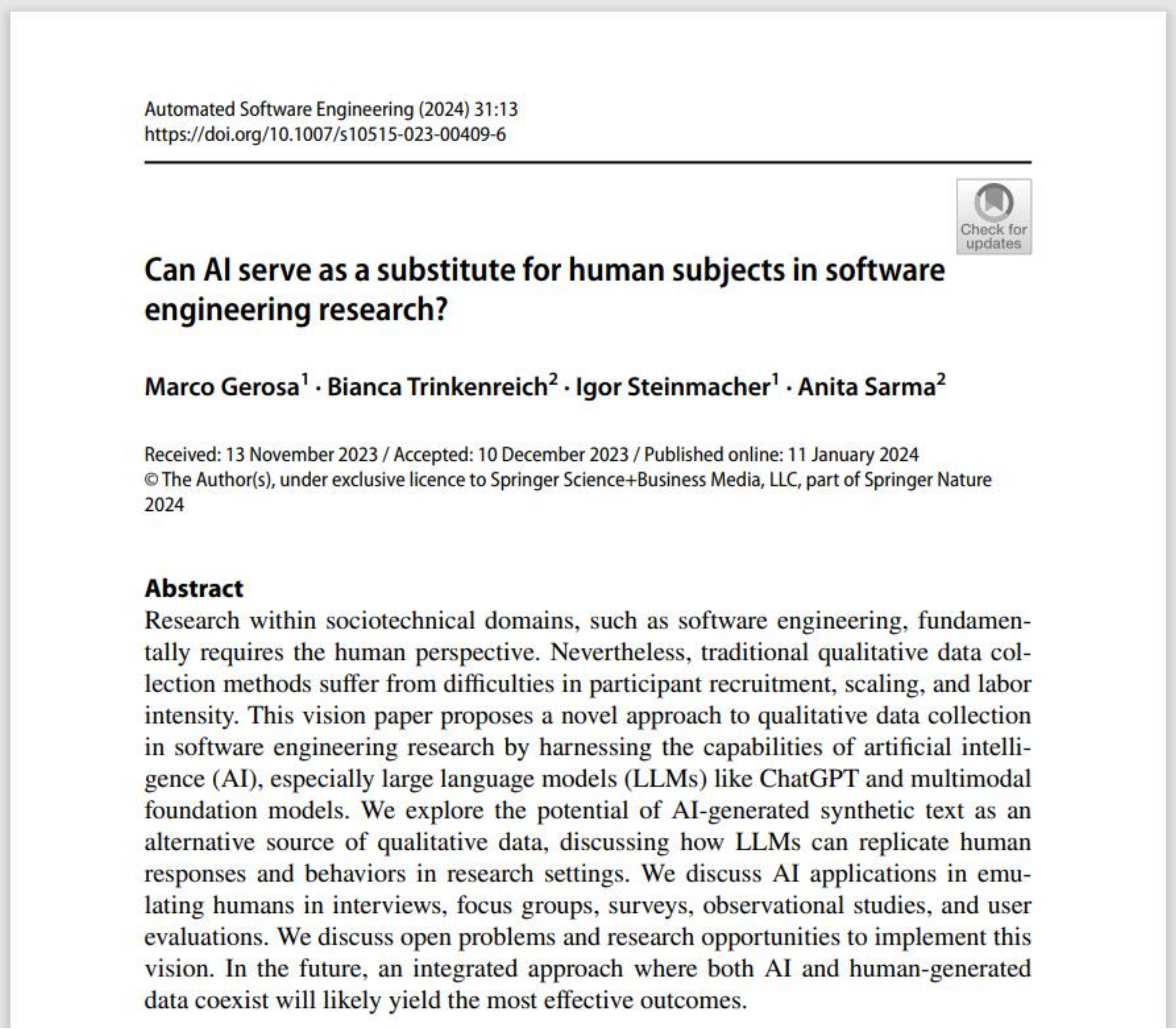

Automated Software Engineering (2024) 31:13
https://doi.org/10.1007/s10515-023-00409-6

Can AI serve as a substitute for human subjects in software engineering research?

Marco Gerosa[1] · Bianca Trinkenreich[2] · Igor Steinmacher[1] · Anita Sarma[2]

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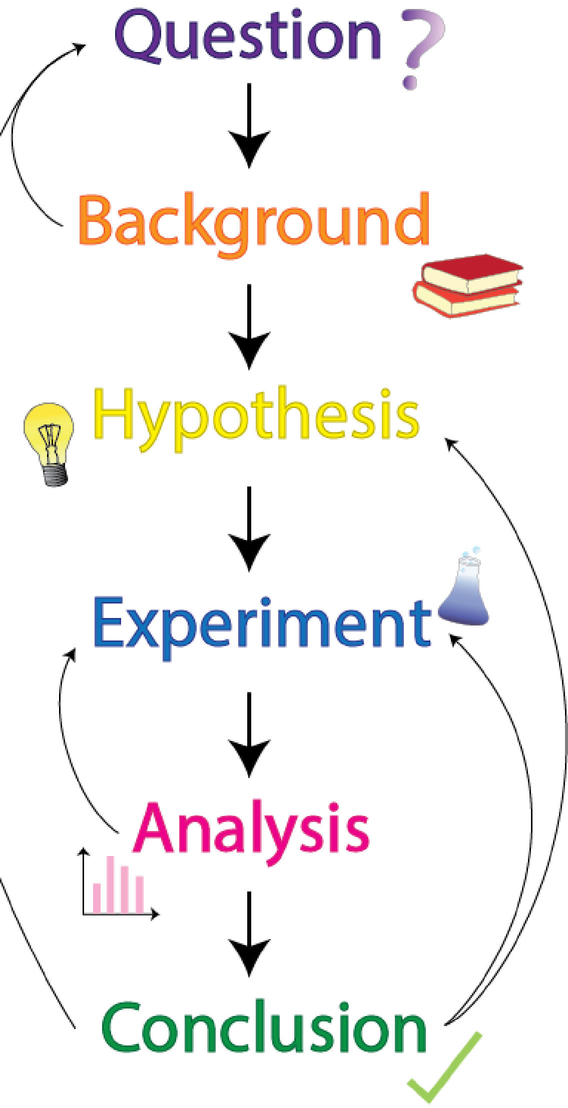
Abstract

Research within sociotechnical domains, such as software engineering, fundamentally requires the human perspective. Nevertheless, traditional qualitative data collection methods suffer from difficulties in participant recruitment, scaling, and labor intensity. This vision paper proposes a novel approach to qualitative data collection in software engineering research by harnessing the capabilities of artificial intelligence (AI), especially large language models (LLMs) like ChatGPT and multimodal foundation models. We explore the potential of AI-generated synthetic text as an alternative source of qualitative data, discussing how LLMs can replicate human responses and behaviors in research settings. We discuss AI applications in emulating humans in interviews, focus groups, surveys, observational studies, and user evaluations. We discuss open problems and research opportunities to implement this vision. In the future, an integrated approach where both AI and human-generated data coexist will likely yield the most effective outcomes.

Tool

The Scientific Method



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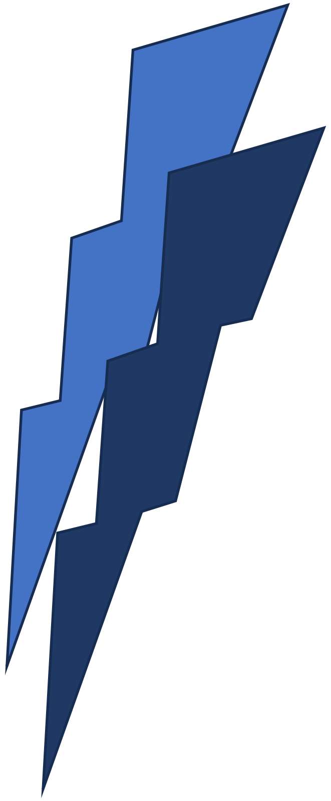
Disruption

- Phenomena
- Methods
- Theories
- Threats
- Ethics
- Tool

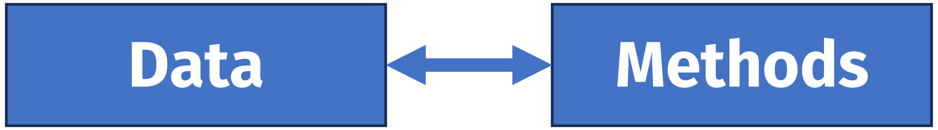


The Big Picture

Data

> “Empirical software engineering is the study of **software-related artifacts** for the characterization, understanding, evaluation, prediction, control, management, or improvement through qualitative or quantitative analysis.”
>
> [Harrison and Basili]

The Big Picture



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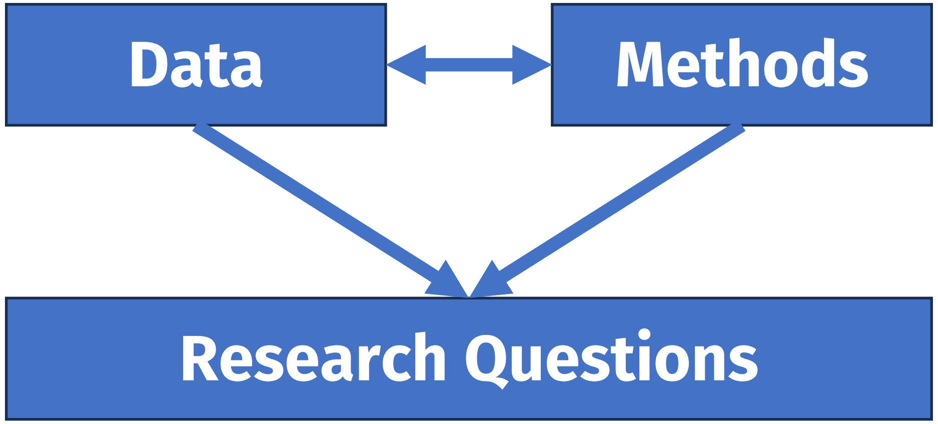
The Big Picture



Data

Methods

Research Questions

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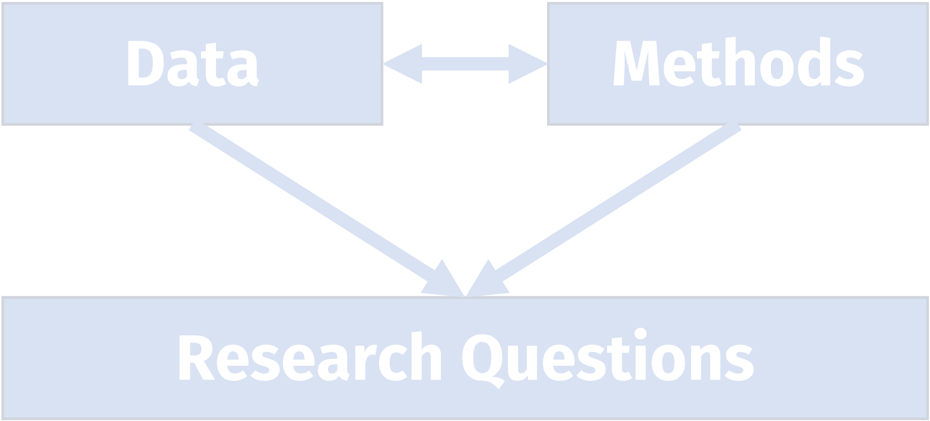
[Harrison and Basili]

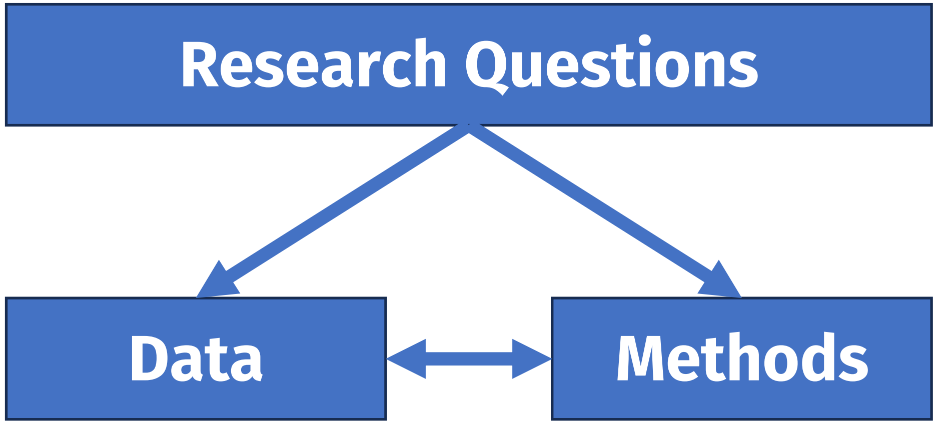
The Big Picture



Data

Methods

Research Questions



Research Questions

Data

Methods

"Empirical software engineering is the study of **software-related artifacts** for the characterization, understanding, evaluation, prediction, control, management, or improvement through qualitative or quantitative analysis."

[Harrison and Basili]

"Quantifying the evidence or making sense of it in qualitative form, a researcher can answer **empirical questions**, which should be clearly defined and answerable with the evidence collected (usually called data)."

[Wikipedia]

The Role of EMSE in the LLM Era

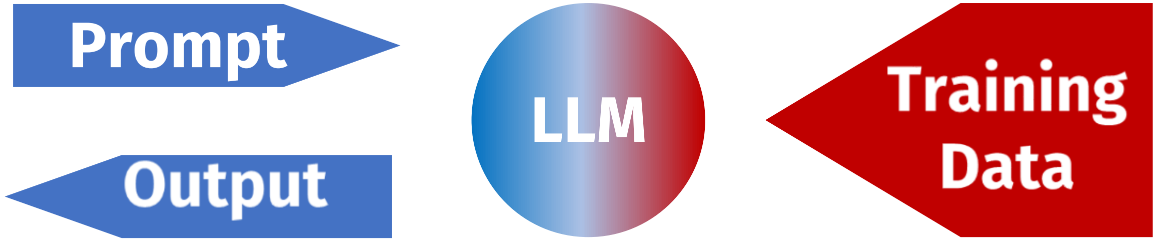
Prompt

Output

LLM

Training Data

The Role of EMSE in the LLM Era



Prompt

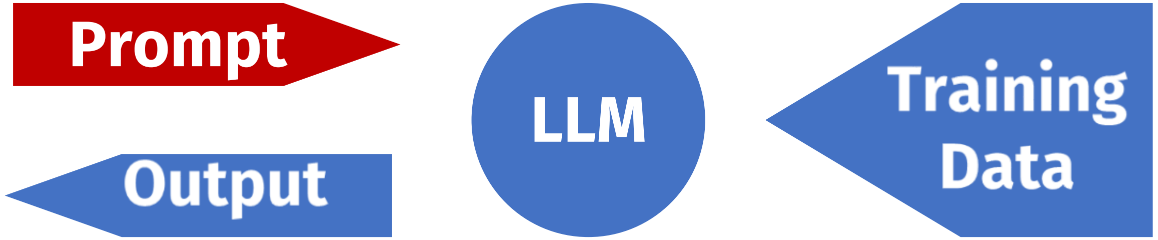
Output

LLM

Training Data

We know the data!

The Role of EMSE in the LLM Era



LLM interactions are data, too

Prompt

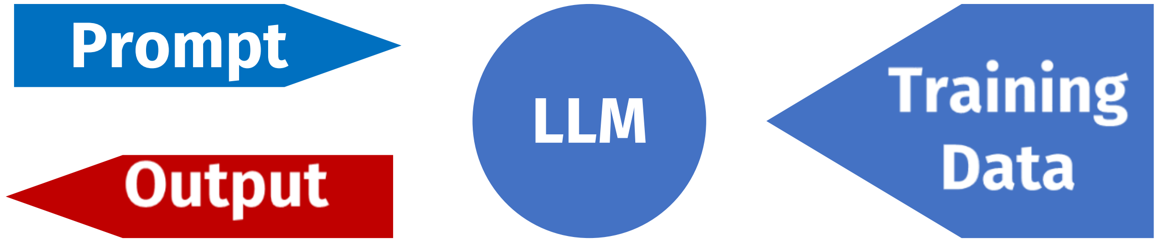
Output

LLM

Training Data

We know the data!

The Role of EMSE in the LLM Era

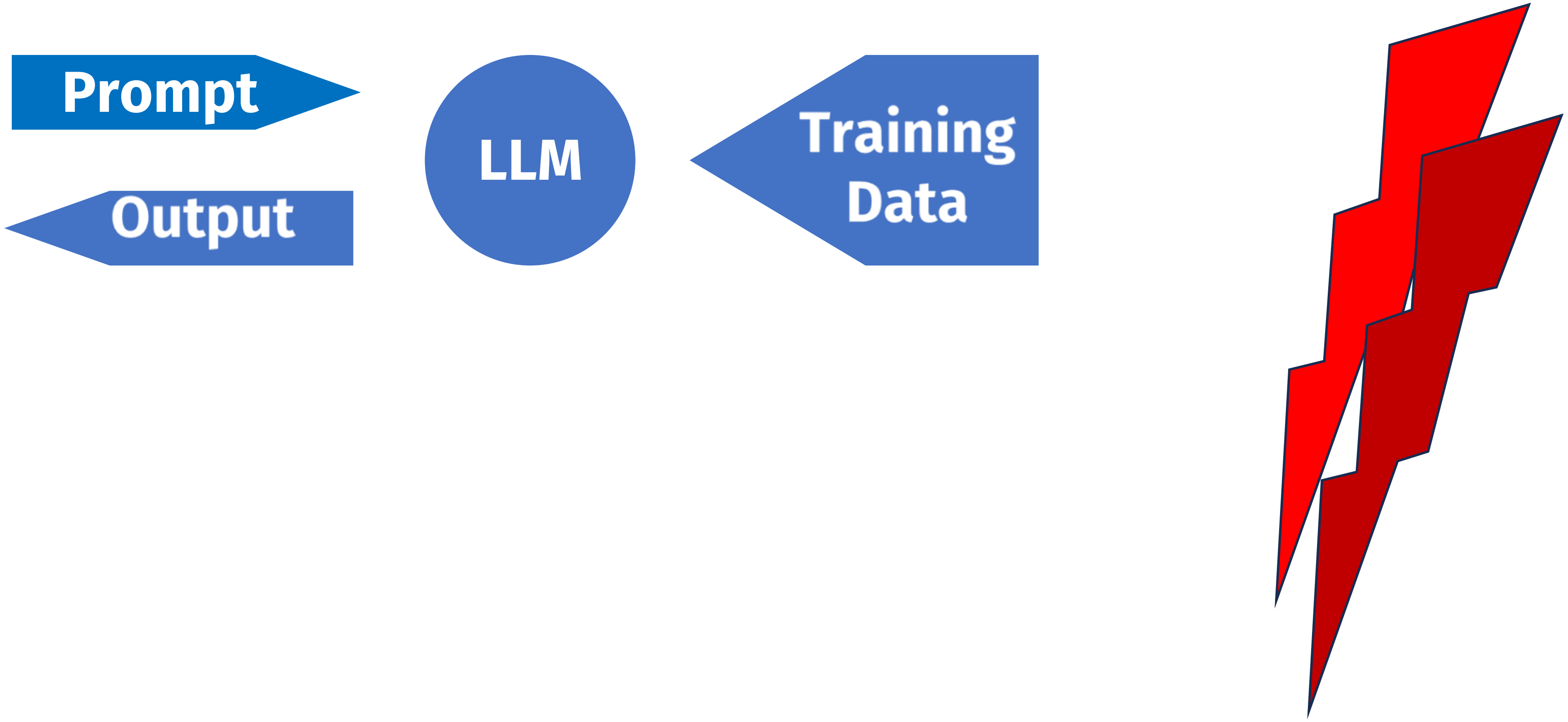


LLM interactions are data, too

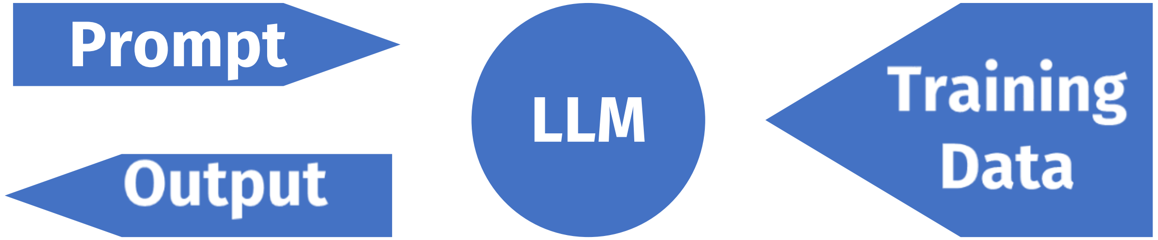
LLM output beyond quality

We know the data!

The Role of EMSE in the LLM Era



Let’s start with the research questions!



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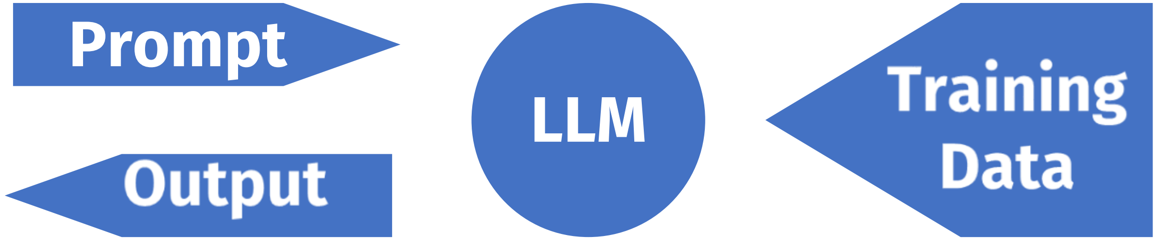

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