The Role of Generative AI in Advanced Programming Education

Künstliche Intelligenz in der Lehre

KEYNOTE, JUBILÄUMSFEIER 20 JAHRE FNMA, NOVEMBER 2023

Jürgen Cito

Assistant Professor

TECHNISCHE UNIVERSITÄT WIEN

@citostyle

IPA Lab @ TU WIEN TECHNISCHE UNIVERSITÄT WIEN

Interactive Programming & Analysis Lab

Empirical Understanding: Understand the underlying structures and artifacts that govern exploration and experimentation in computational tasks.

System Building: We design, build, and evaluate interventions in the form of systems that either automate or augment human ability to better deal with these structures and artifacts.

Lab Members

Jürgen Cito (PI)

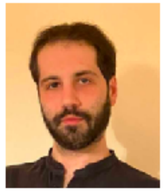
Michael Schröder
Program Analysis for
Ad-hoc Parsing Code

Andreas Happe
Reinforcement Learning
for Penetration Testing

Markus Böck
Program Analysis for
Probabilistic Programs

Nathanael Nussbaumer
Debugging for
Probabilistic Programs

Lucie David
University of Leipzig
Machine Learning for
Microbenchmark Performance



Francesco Altiero
University of Napoli
Dependency-aware
Test Prioritization

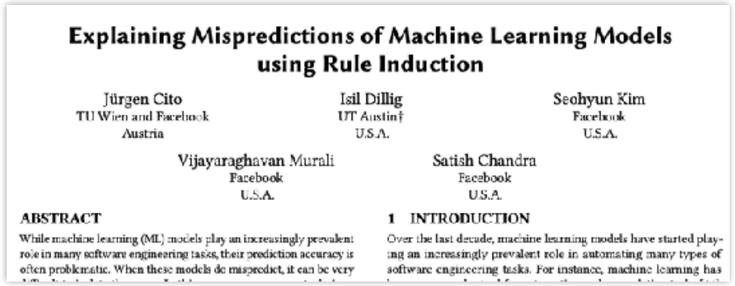
IPA Lab @ TU WIEN TECHNISCHE UNIVERSITÄT WIEN

Interactive Programming & Analysis Lab

AI in Research

Explainability of Large Language Models

Visiting Researcher Meta



Explaining Mispredictions of Machine Learning Models using Rule Induction

Jürgen Cito, TU Wien and Facebook, Austria
Isil Dillig, UT Austin†, U.S.A.
Seohyun Kim, Facebook, U.S.A.
Vijayaraghavan Murali, Facebook, U.S.A.
Satish Chandra, Facebook, U.S.A.

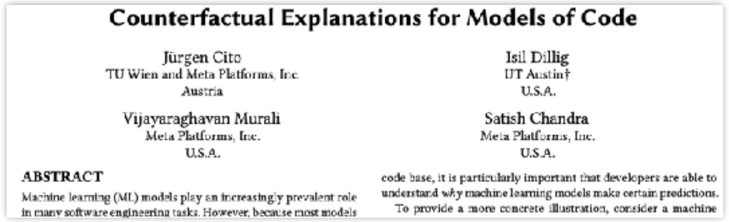
ABSTRACT

While machine learning (ML) models play an increasingly prevalent role in many software engineering tasks, their prediction accuracy is often problematic. When these models do mispredict, it can be very

1 INTRODUCTION

Over the last decade, machine learning models have started playing an increasingly prevalent role in automating many types of software engineering tasks. For instance, machine learning has

FSE'21



Counterfactual Explanations for Models of Code

Jürgen Cito, TU Wien and Meta Platforms, Inc, Austria
Isil Dillig, UT Austin†, U.S.A.
Vijayaraghavan Murali, Meta Platforms, Inc., U.S.A.
Satish Chandra, Meta Platforms, Inc., U.S.A.

ABSTRACT

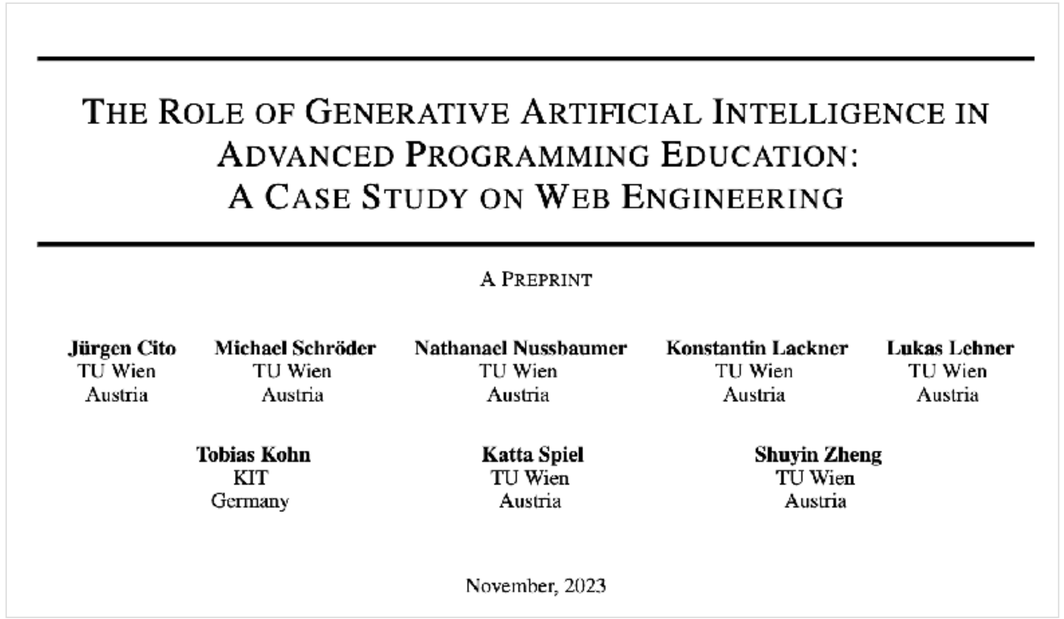
Machine learning (ML) models play an increasingly prevalent role in many software engineering tasks. However, because most models

code base, it is particularly important that developers are able to understand why machine learning models make certain predictions. To provide a more concrete illustration, consider a machine

ICSE'22 SEIP

AI in Teaching

Studying Student Perception of Generative AI



THE ROLE OF GENERATIVE ARTIFICIAL INTELLIGENCE IN ADVANCED PROGRAMMING EDUCATION: A CASE STUDY ON WEB ENGINEERING

A PREPRINT

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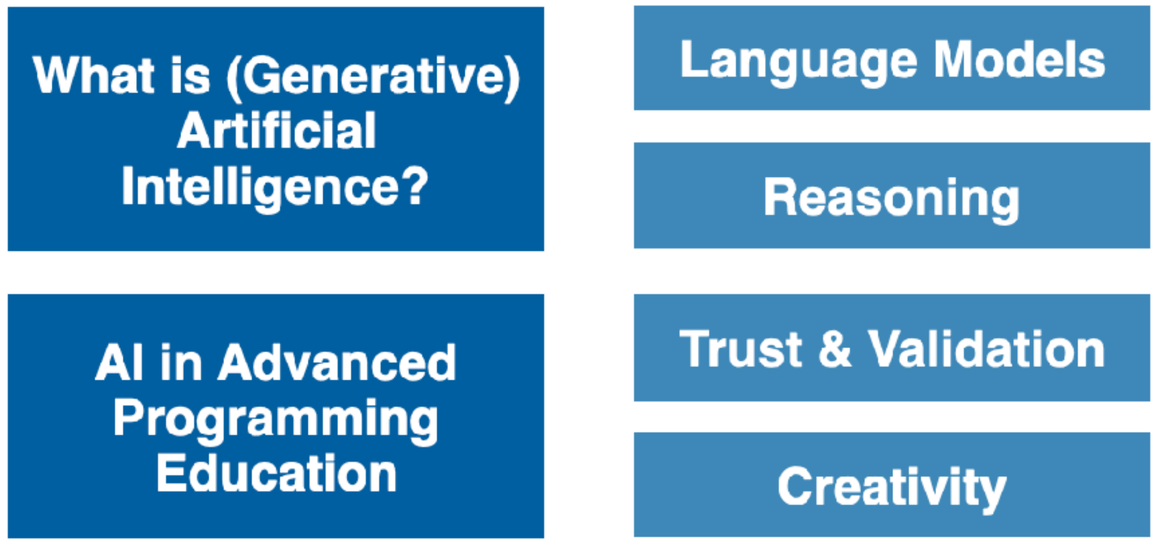
Tobias Kohn, KIT, Germany
Katta Spiel, TU Wien, Austria
Shuyin Zheng, TU Wien, Austria

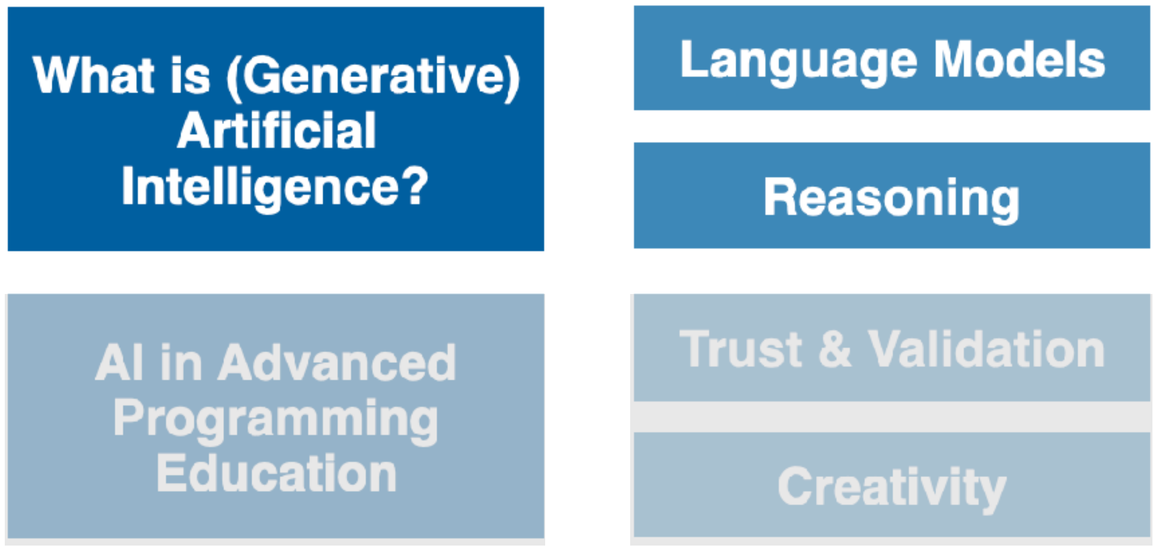
November, 2023

Generative AI in higher education



Generative AI in higher education

Part I



What is (generative) artificial intelligence?

Deep Learning

Symbolic AI

Expert Systems

Large Language Models

Machine Learning

Generative
Pretrained
Transfomers

Reinforcement Learning

ChatGPT

Transfer Learning

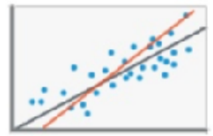
Computational Cognitive Science

Machine Learning 101

Provides computational means to learn models
without being explicitly programmed

supervised

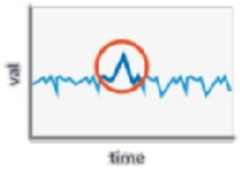
Classification
(supervised – predictive)



Regression
(supervised – predictive)

unsupervised

Clustering
(unsupervised – descriptive)

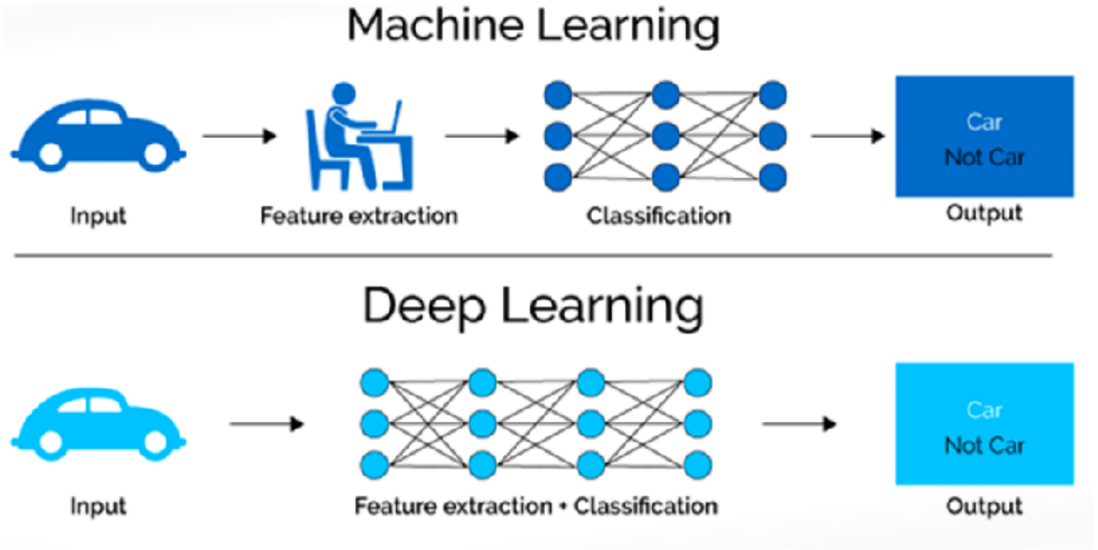


Anomaly Detection
(unsupervised – descriptive)

Credit: https://www.slideshare.net/LuMa921/deep-learning-a-visual-introduction/7

Deep Learning 101

Use neural networks to learn models from data
where features cannot be explicitly expressed



Credit: http://blog.thinkwik.com/insights-of-the-machine-learning-and-the-deep-learning/

Deep Learning 101

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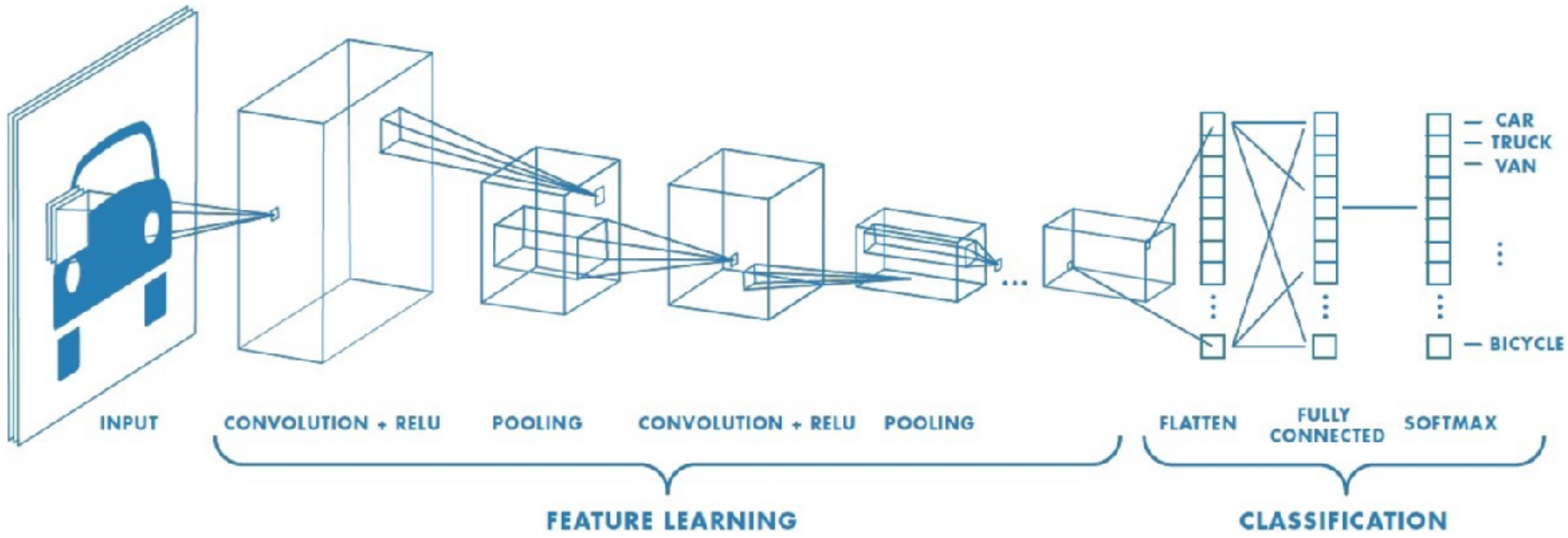


Credit: Introduction to Deep Learning https://www.youtube.com/watch?v=3cSjsTKtN9M

Large Language Models / Generative Pretrained Transformers
Or: How does ChatGPT work?

Generative Pretraining (self-supervised)

Next element | History

$$P_\theta(X_{t+1} = x_{t+1} \mid x_1, \ldots, x_n)$$

Optimize parameters to maximize probability

History h =

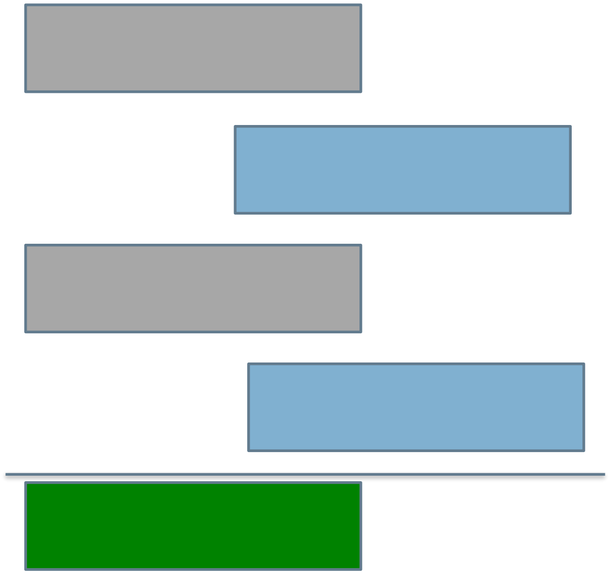
Annas Haus
hat die Farbe _

$$P_\theta(? = "blau" \mid h) = 0.3$$
$$P_\theta(? = "braun" \mid h) = 0.2$$
$$\ldots$$
$$P_\theta(? = "lavender" \mid h) = 0.005$$
$$P_\theta(? = "Brotfabrik" \mid h) = 0.0$$

Supervised fine-tuning (InstructGPT)

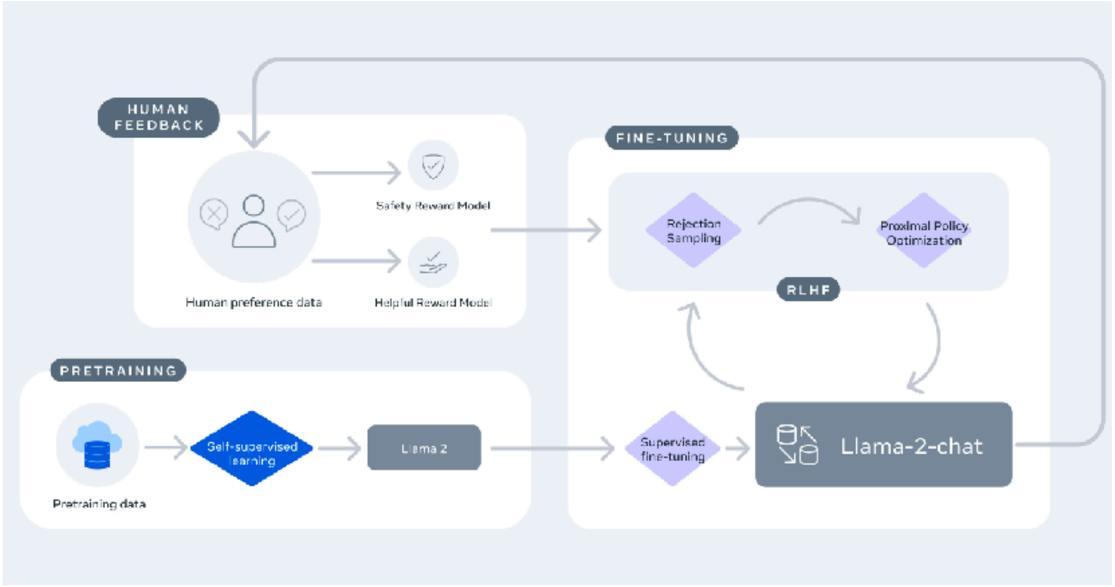
Chat History

(Conversations between ideal chatbot and human user)

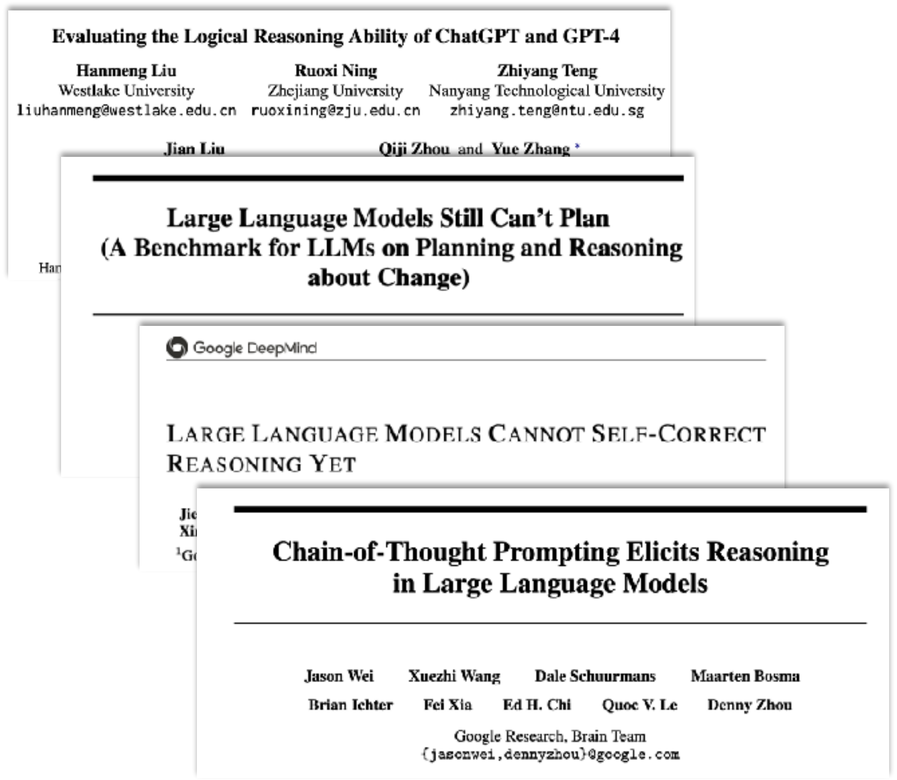


Next response

Reinforcement Learning with Human Feedback



Reasoning in Large Language Models



Difficulty to reason especially when encountering out-of-distribution inputs

Limited contextual understanding leads do hallucinations

Promising directions:

(1) Chain-of-Thought Prompting

(2) Combining LLMs with Symbolic Solvers

(3) Retrieval-augmented language models

Excursion: Creativity

Can AI be creative?

My answer in **2019**: No
My answer in **2023**: Not sure

Salzburger Nachrichten SAMSTAG, 22. JUNI 2019

WIRTSCHAFT 15

„Künstliche Intelligenz ist nicht kreativ“

Was schlaue Algorithmen nicht können. Und warum sie auch von unseren schwächsten Eigenschaften lernen.

IRIS BURTSCHER

Der österreichische Wissenschafter Jürgen Cito (29) forscht am Massachusetts Institute of Technology (MIT) in Boston über künstliche Intelligenz (KI) und kooperiert dort auch mit US-Konzernen wie Facebook, IBM oder Boeing.

SN: Wer ist schlauer, ein zweijähriges Kind oder eine künstliche Intelligenz?
Ein zweijähriges Kind. Weil es viel

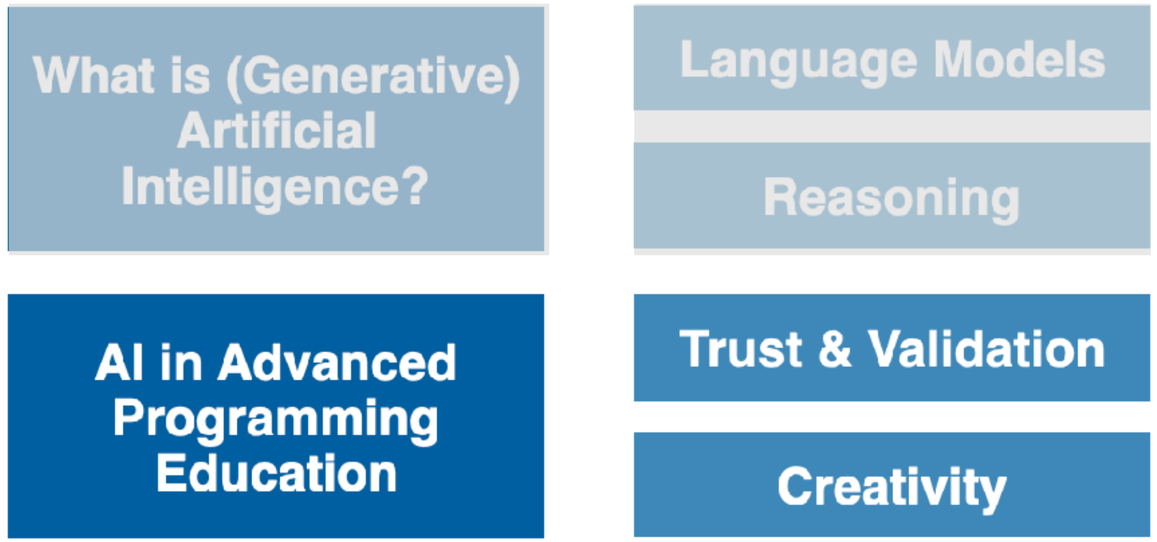
etwa von Systemen gelenkt, die immer mehr über unser Kaufverhalten lernen. Das kann man negativ oder positiv sehen: Weil man zu mehr Käufen verführt wird oder weil man vielleicht bessere Kaufentscheidungen trifft.

SN: Die australische Versicherung Suncorp hat mehrere Monate lang parallel zu ihren Sachbearbeitern auch den IBM-Supercomputer Watson die gleichen Fälle bearbeiten

Einen Kunststil erschaffen kann KI nicht. Bilder adaptieren schon. Das Programm Deepart von Wissenschaftern der Uni Tübingen ermöglicht es, ein Foto von Jürgen Cito mit dem Stil von Kandinsky zu mischen.

Generative AI in higher education

Part II



Context: Advanced Programming Course

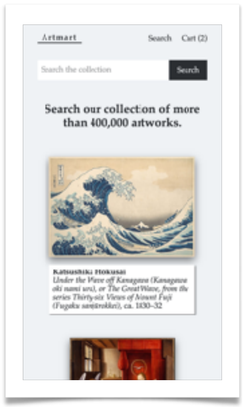
Web Engineering @ TU Wien

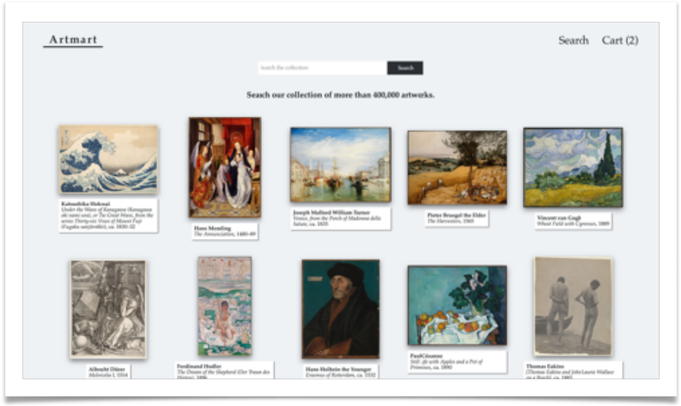
Scale:

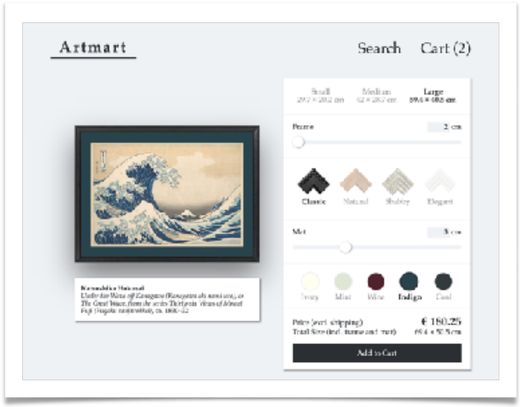
- ~400 students
- Automated Grading (manually written checks)
- AI-supported Grading

Support:

- 1 Professor
  1 University Assistant
  1 Head TA
- 5 Tutors







The Role of AI in Advanced Programming Education

How are students using AI tools to solve advanced programming exercises?

What other information sources are they using?

What is the interaction between AI tools and other information sources?

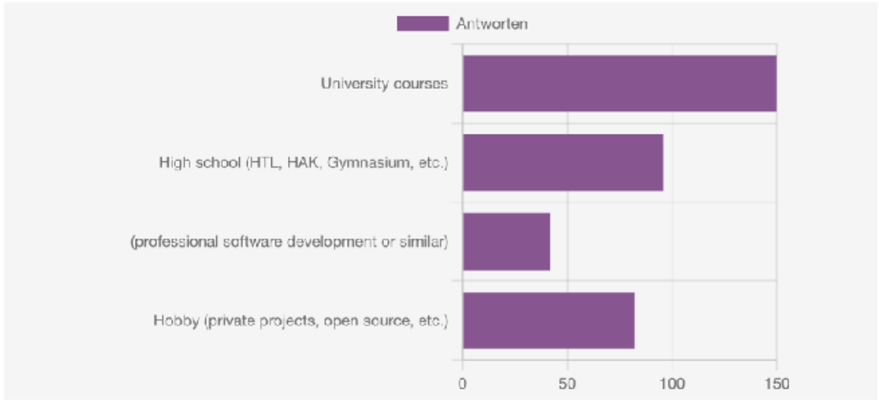
Study Demographics

The Role of AI in Advanced Programming Education

Bachelor students in Computer Science and Business Informatics

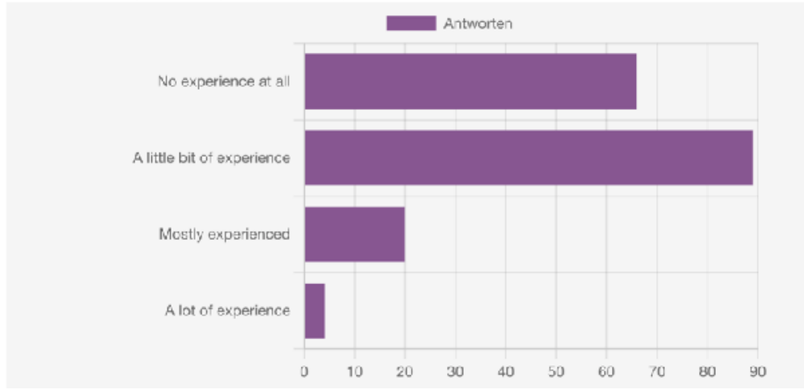
Prior Programming Experience

In which context have you already had programming experience before starting this course?



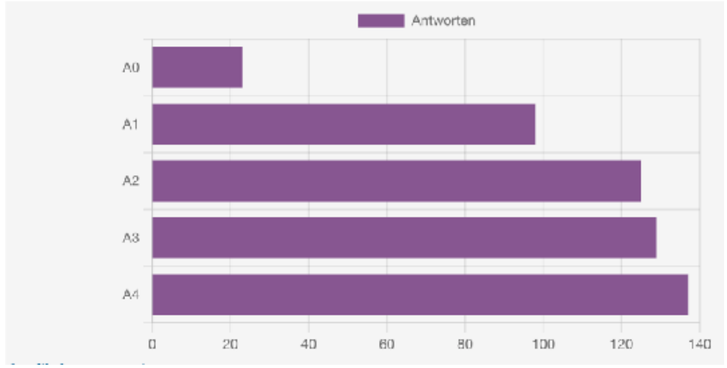
Prior AI tool experience

Did you have previous experience with AI tools (before the course) to support software development (ChatGPT, Copilot, etc.)?



AI tool use throughout the course

For which assignments did you use an AI tool as part of this course?



Study Methodology

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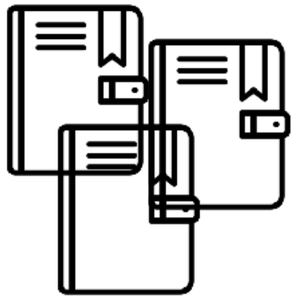
Diary study: Students submit open-ended diaries as they are solving exercises that capture information source use *including* AI tools

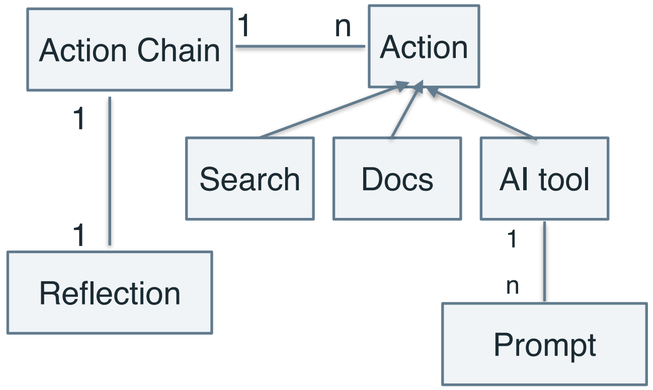
~150 (unstructured) diaries



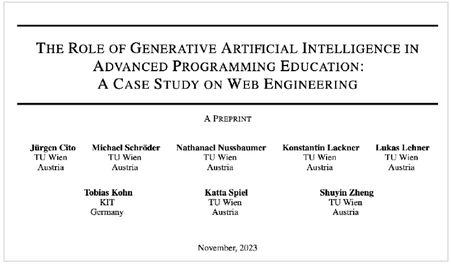
Inductive analysis on sample diaries
(by 4 researchers)

Subsequent discussion of results and distillation into a commonly agreed model

Action Chain Model



Qualitative Analysis —> Quantitative Insights



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November, 2023

7 researchers analyze all diaries using qualitative analysis methods and distill it into our action chain model

AI vs. Non-AI interactions

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```
select count(*), at.name from "ActionType" at join "Action"
a on a."typeId" = at.id group by 2 order by 1 desc;
```

count	name
508	AI Interaction
331	Reflections
299	Documentation
118	Problem
54	Human Interaction
51	Search

What interactions is AI replacing?

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AI interaction goals (N=508)

count	name	
136	Documentation Replacement	**27%**
82	Full Implementation	**16%**
68	Code Explanation	**13%**
65	Directions	**13%**
56	Modifying solution/code	**11%**
55	Refinement	**11%**
46	Fault Localization	**9%**

Human interaction goals (N=54)

	count	name
19%	10	Documentation Replacement
0%	0	Full Implementation
5%	3	Code Explanation
24%	13	Directions
3%	2	Modifying solution/code
0%	0	Refinement
48%	26	Fault Localization

Student Problems & Reflections

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Reflections on AI use (N=160)

count	value	
69	"Positive"	43%
57	"Neutral"	36%
34	"Negative"	21%

Smart Documentation

"It really helps to deeply understand things. I don't use YouTube or any other videos at all anymore because AI explains it easily and in a fast way"

Helper in need

ChatGPT helped me by explaining code, which I didn't understand. Furthermore it helped me finding some errors in my code

Only Basics

For basic tasks it was really helpful. For tasks where more context was needed it was not very helpful

Frustration

Just doing it yourself might have been the faster, then correcting some AI delusions

Alignment

The time it takes for me to write the prompt (maybe even correct it) and then validate what the AI wrote... in that time I could probably write it myself.

Validation & Trust

If you don't already have an understanding of what you're coding, it will be very hard to tell whether the problem in your code comes from faulty code the AI gave you or if you have an error somewhere else

Künstliche Intelligenz in der Lehre

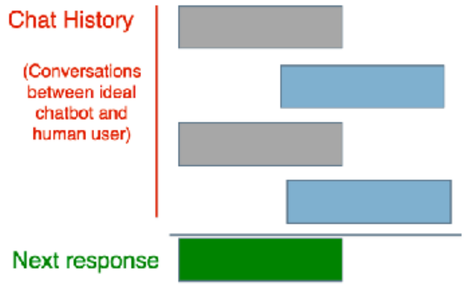
Was ist KI?

Reasoning und Kreativität als Optimierungsproblem

Next element History

$$P_\theta(X_{t+1} = x_{t+1} \mid x_1, \ldots, x_n)$$

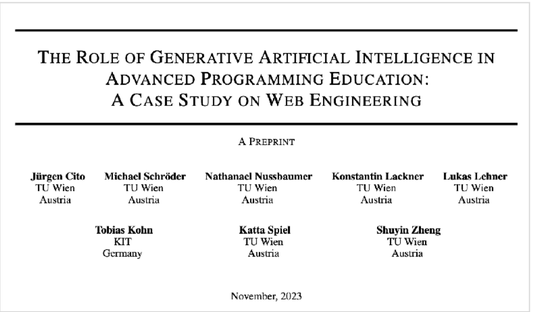
Optimize parameters to maximize probability



KI in der Fortgeschrittenen Programmierlehre

Wissensbasis, Vertrauen, Validieren, und Frustration

Smart Documentation	Frustration
Helper in need	Alignment
Only Basics	Validation & Trust



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