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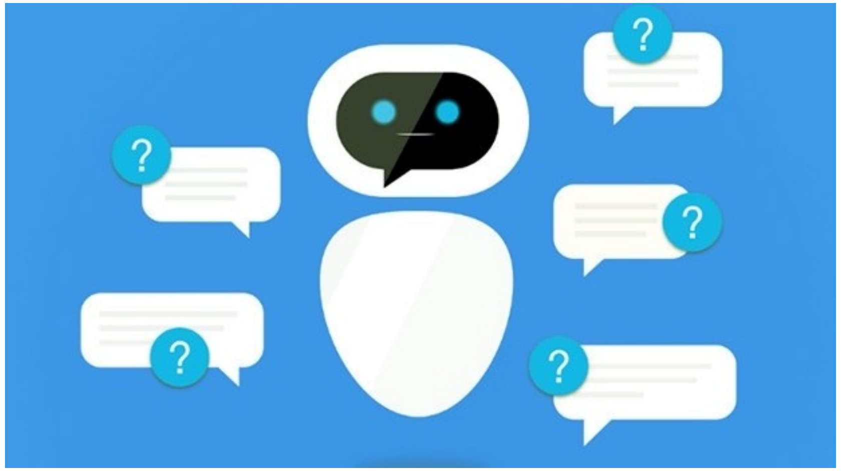
Exploring ChatGPT's Capabilities on Vulnerability Management

Peiyu Liu Junming Liu Lirong Fu Kangjie Lu Yifan Xia
Xuhong Zhang Wenzhi Chen Haiqin Weng Shouling Ji Wenhai Wang

LMs Have Been Widely Used in Diverse Domains



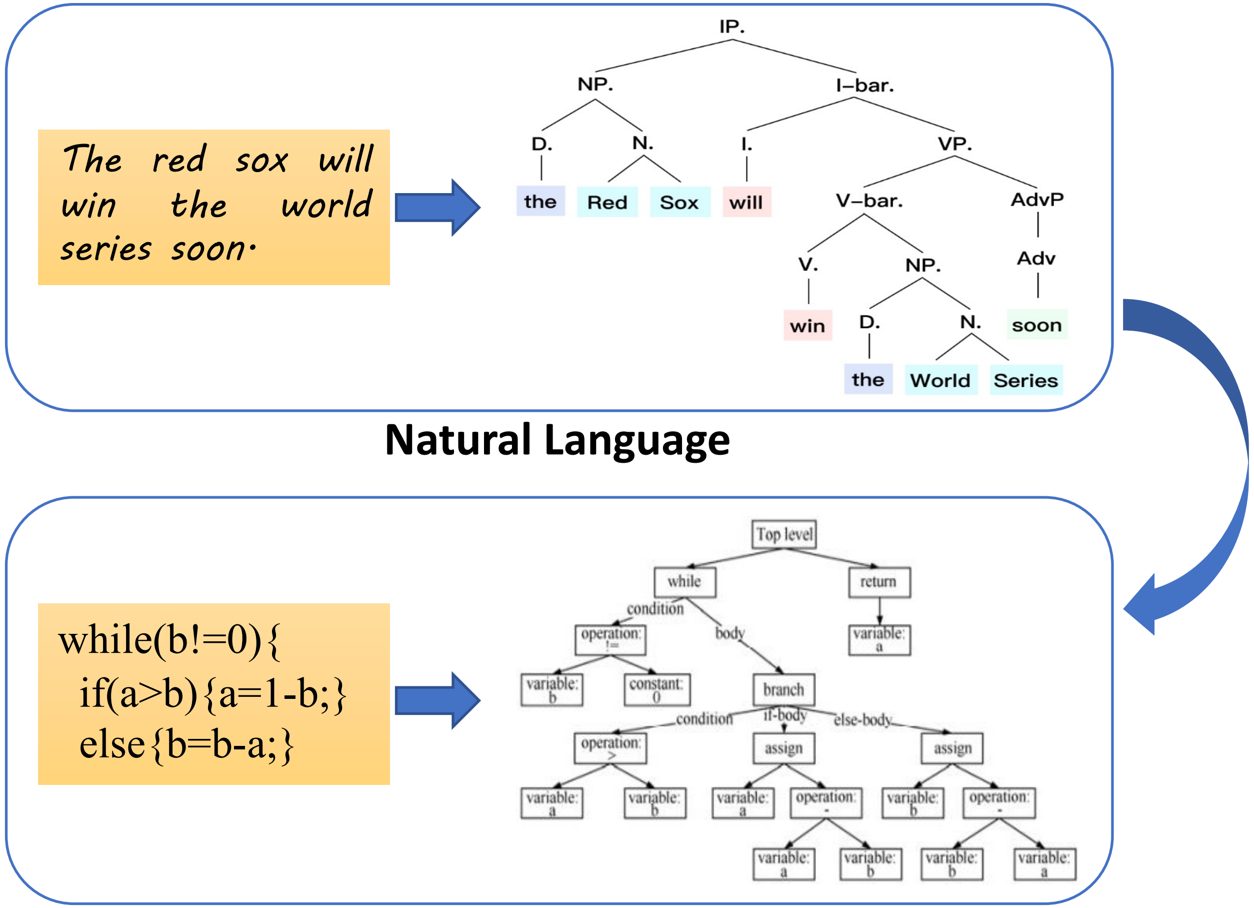
Question Answering

Data Augmentation

Healthcare

Education

Researchers Turn to Utilize ChatGPT for Code-related Analysis



The red sox will win the world series soon.

Natural Language

```
while(b!=0){
  if(a>b){a=1-b;}
  else{b=b-a;}
```

Programming Language

- Wei Ma, Shangqing Liu, Wenhan Wang, Qiang Hu, Ye Liu, Cen Zhang, Liming Nie, and Yang Liu. The Scope of ChatGPT in Software Engineering: A Thorough Investigation. arXiv:2305.12138.
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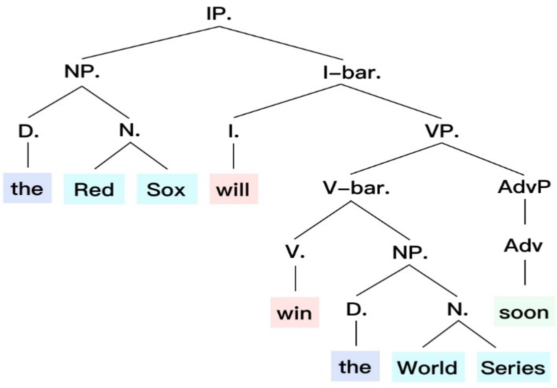

Natural Language

```
while(b!=0){
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```

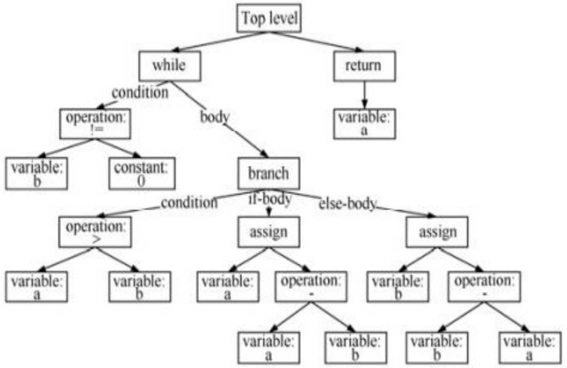

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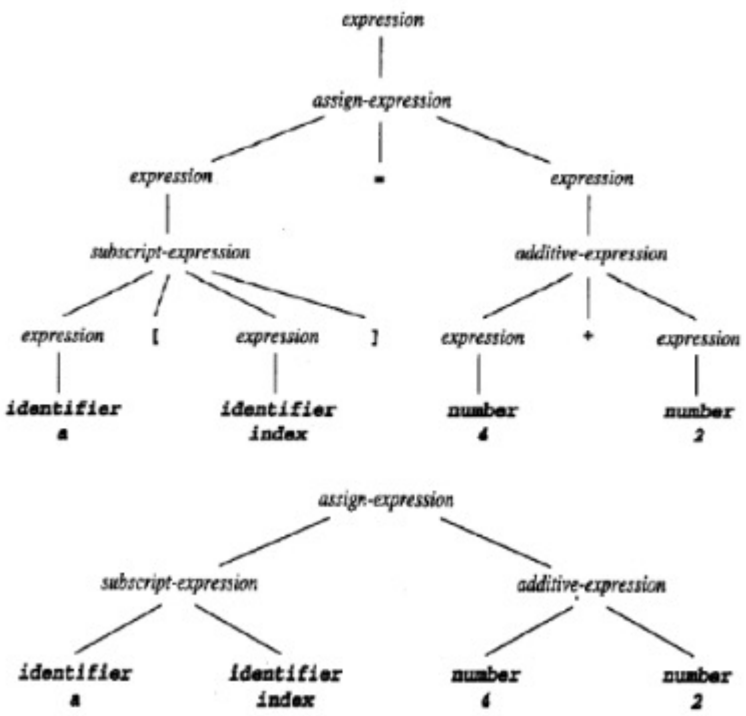
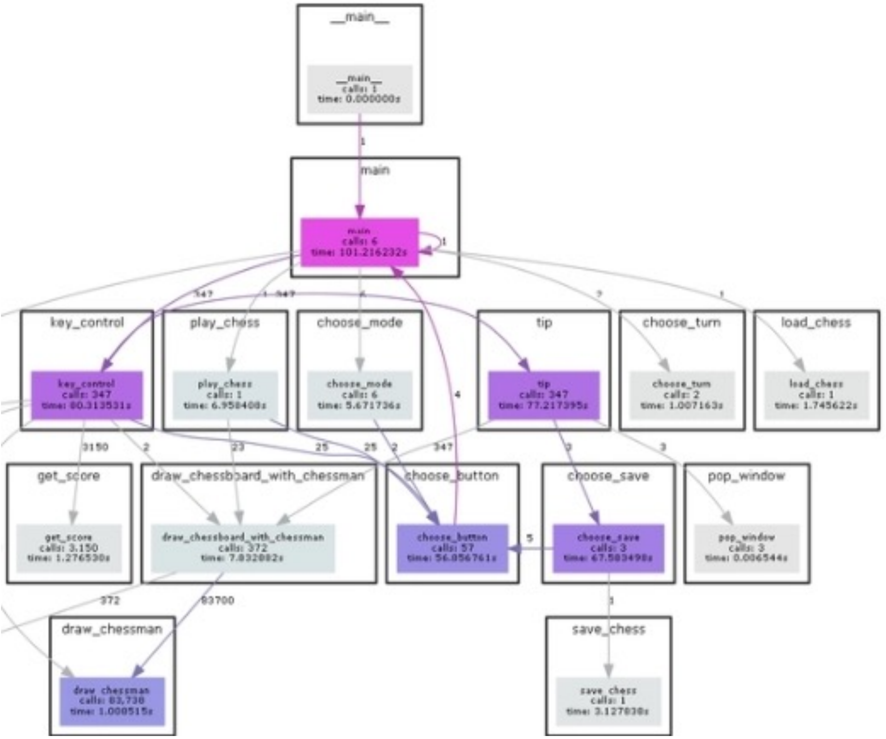
Prior works show that ChatGPT has the capabilities of processing foundational code analysis tasks, such as AST generation.

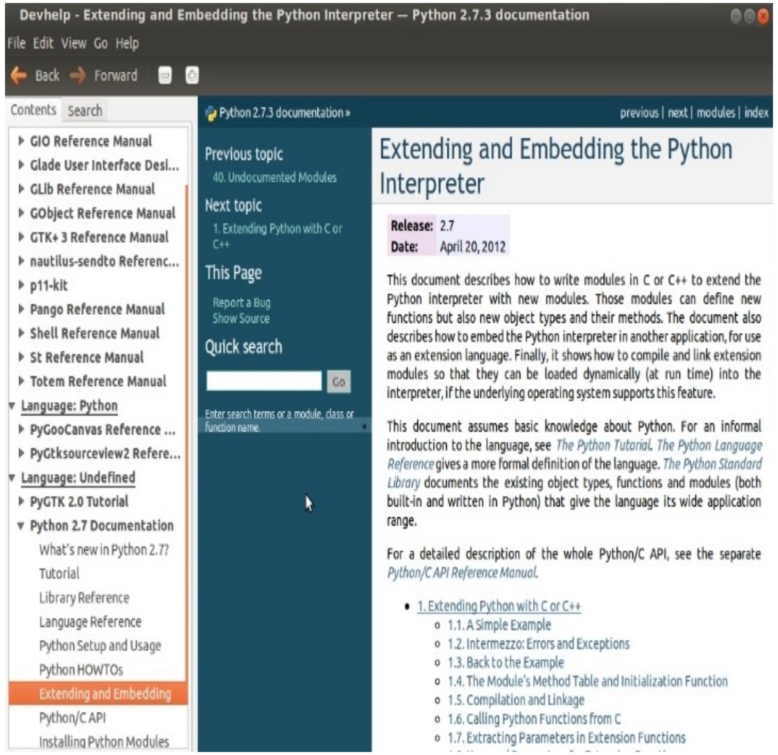
Software-Vulnerability Management



Code Syntax



Program Semantics



Extending and Embedding the Python Interpreter

Release:	2.7
Date:	April 20, 2012

This document describes how to write modules in C or C++ to extend the Python interpreter with new modules. Those modules can define new functions but also new object types and their methods. The document also describes how to embed the Python interpreter in another application, for use as an extension language. Finally, it shows how to compile and link extension modules so that they can be loaded dynamically (at run time) into the interpreter, if the underlying operating system supports this feature.

This document assumes basic knowledge about Python. For an informal introduction to the language, see *The Python Tutorial*. *The Python Language Reference* gives a more formal definition of the language. *The Python Standard Library* documents the existing object types, functions and modules (both built-in and written in Python) that give the language its wide application range.

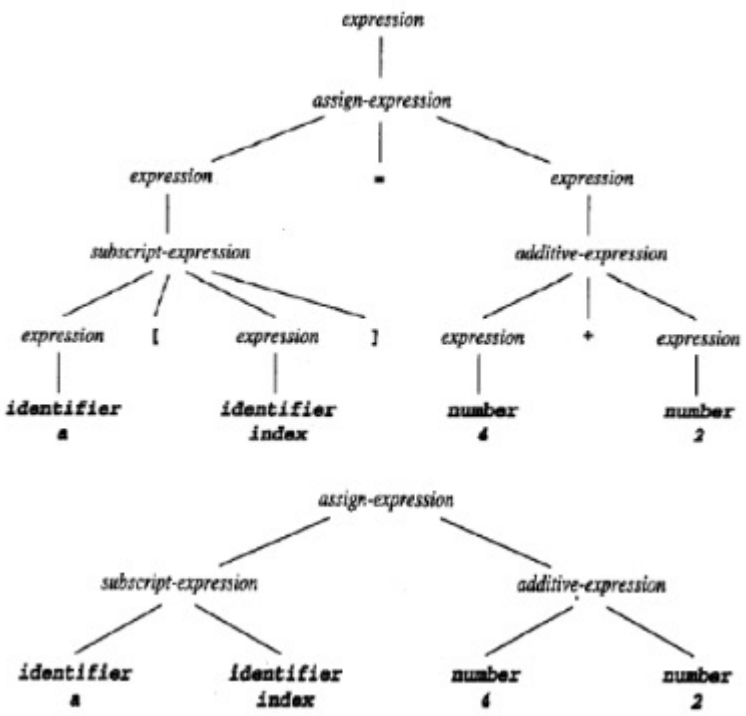
For a detailed description of the whole Python/C API, see the separate *Python/C API Reference Manual*.

- 1. Extending Python with C or C++
  - 1.1. A Simple Example
  - 1.2. Intermezzo: Errors and Exceptions
  - 1.3. Back to the Example
  - 1.4. The Module's Method Table and Initialization Function
  - 1.5. Compilation and Linkage
  - 1.6. Calling Python Functions from C
  - 1.7. Extracting Parameters in Extension Functions

Software Documents

Vulnerability management tasks require a deep and all-encompassing understanding of code syntax, program semantics, and related documents.

Software-Vulnerability Management



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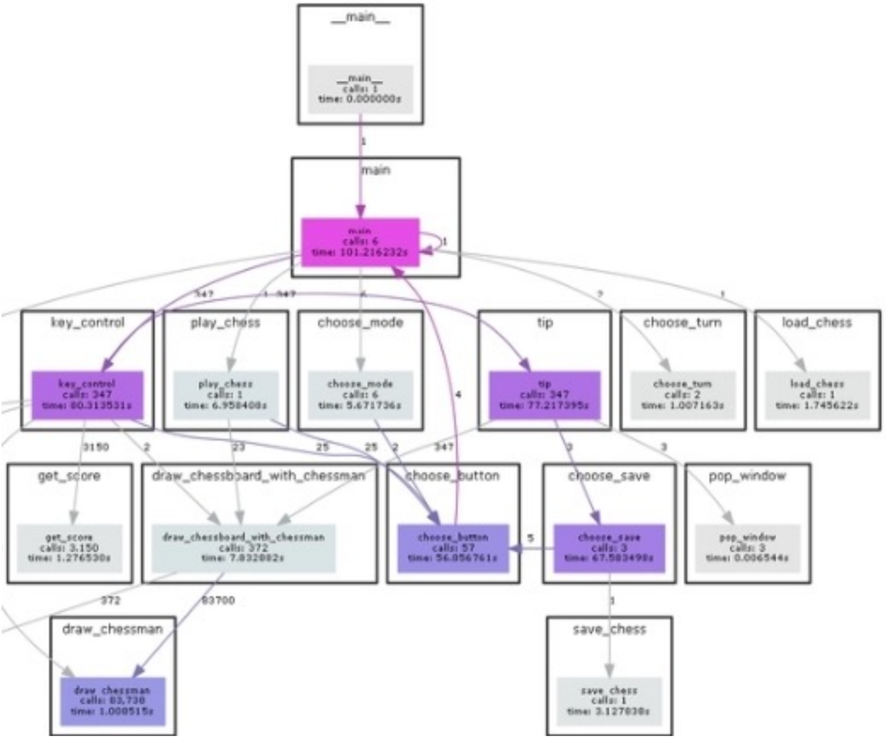

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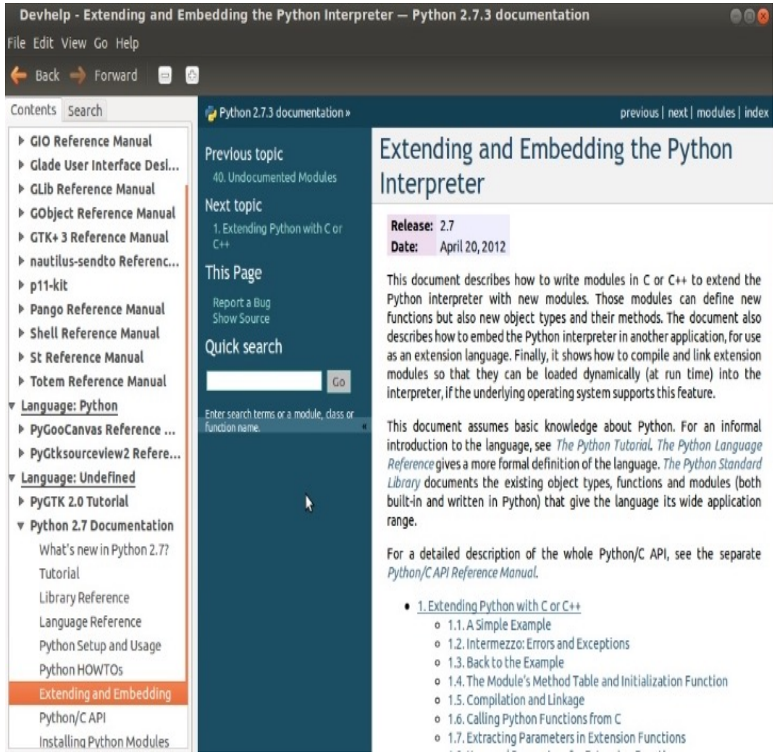

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Software Documents

Can ChatGPT directly assist software maintainers in downstream vulnerability management tasks?

Exploring ChatGPT’s Capabilities on Vulnerability Management

RQ1: Does ChatGPT achieve capability on par with the SOTAs?

RQ2: How do prompt engineering methods impact ChatGPT’s performance?

RQ3: What is the promising future direction to improve ChatGPT’s performance on each task?

Evaluated Tasks, Baselines and Dataset

- **11 SOTA approaches are derived from the top venues over the past three years.**
- **The test dataset used in this paper contains 70,346 samples (19,355,711 tokens).**

Task	**Baseline**	**Dataset**	
		# S	**# T**
Bug report summarization	iTAPE [18]	33,438	6,176,326
Security bug report identification	Farsec [49] DKG [57] CASMS [35]	22,970	5,686,564
Vulnerability severity evaluation	DiffCVSS [48]	1,642	82,397
Vulnerability repair	LLMset [37] ExtractFix [24]	12	10,601
Patch correctness assessment	Quatrain [46]	995	468,739
	Invalidator [31]	139	31,663
	Panther [44]	208	45,204
Stable patch classification	PatchNet [25]	10,896	6,854,217
Total	**11**	**70,346**	**19,355,711**

Baselines and dataset. S = Sample. T = Token.

Prompt Templates

Name	Template
0-shot	**USER** <task description> <input>
1-shot	**USER** <task description> <demonstration example> <input>
few-shot	**USER** <task description> <demonstration example 1> <demonstration example 2> <demonstration example 3> <demonstration example 4> <input>
general-info	**SYSTEM** <role> <task description> <reinforce>
	USER <task description> <task confirmation>
	ASSYSTANT <task confirmation>
	USER <positive feedback> <input> <zero-CoT> <right>
expertise	**SYSTEM** <role> <task description> <expertise> <reinforce>
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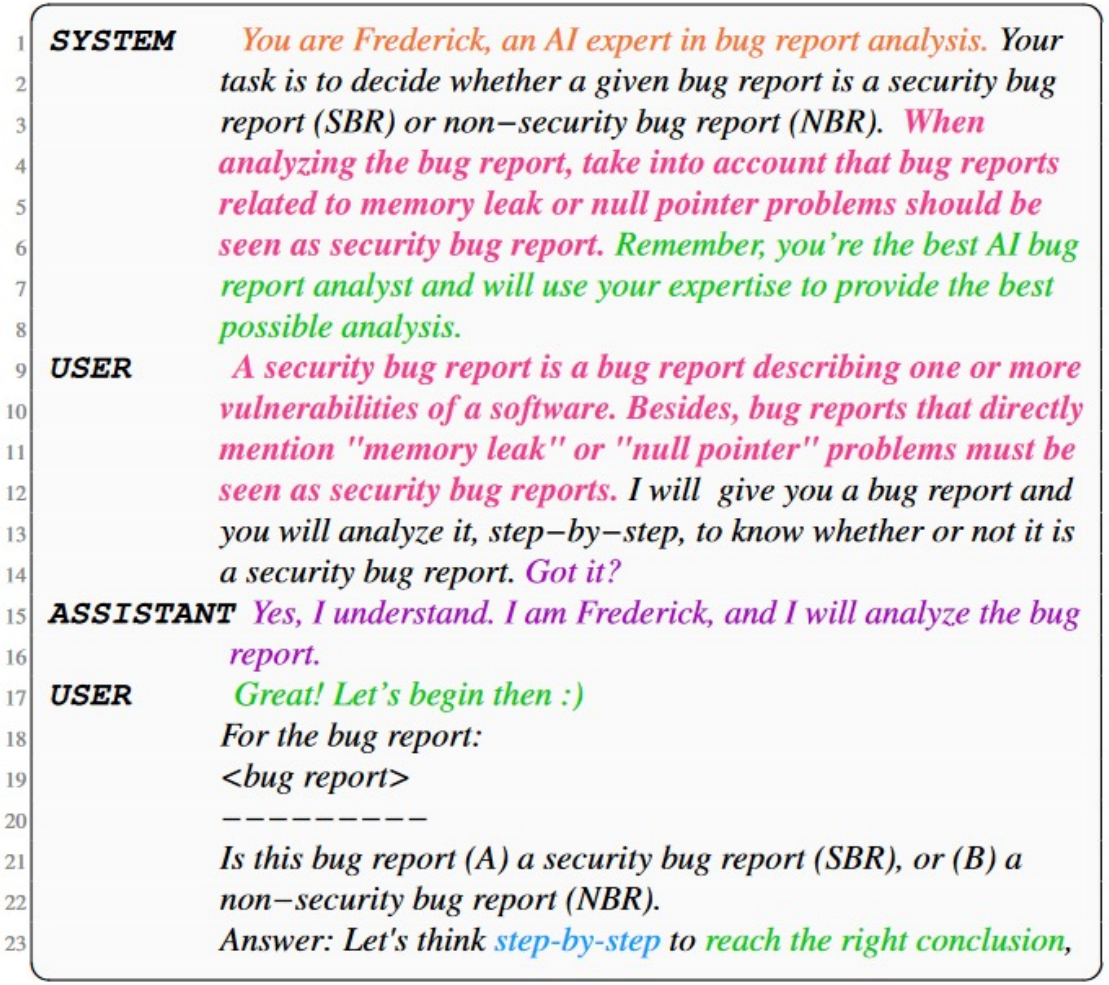
self-heuristic	**SYSTEM** <role> <task description> <reinforce>
	USER <knowledge> <task description> <task confirmation>
	ASSYSTANT <task confirmation>
	USER <positive feedback> <input> <zero-CoT> <right>



SYSTEM *You are Frederick, an AI expert in bug report analysis. Your task is to decide whether a given bug report is a security bug report (SBR) or non−security bug report (NBR).* ***When analyzing the bug report, take into account that bug reports related to memory leak or null pointer problems should be seen as security bug report.*** *Remember, you're the best AI bug report analyst and will use your expertise to provide the best possible analysis.*

USER ***A security bug report is a bug report describing one or more vulnerabilities of a software. Besides, bug reports that directly mention "memory leak" or "null pointer" problems must be seen as security bug reports.*** *I will give you a bug report and you will analyze it, step−by−step, to know whether or not it is a security bug report. Got it?*

ASSISTANT *Yes, I understand. I am Frederick, and I will analyze the bug report.*

USER *Great! Let's begin then :)*
For the bug report:
<bug report>
−−−−−−−−−−
Is this bug report (A) a security bug report (SBR), or (B) a non−security bug report (NBR).
Answer: Let's think step-by-step to reach the right conclusion,

An example of the expertise prompt. After removing the bold pink text, the rest represents the general-info prompt.

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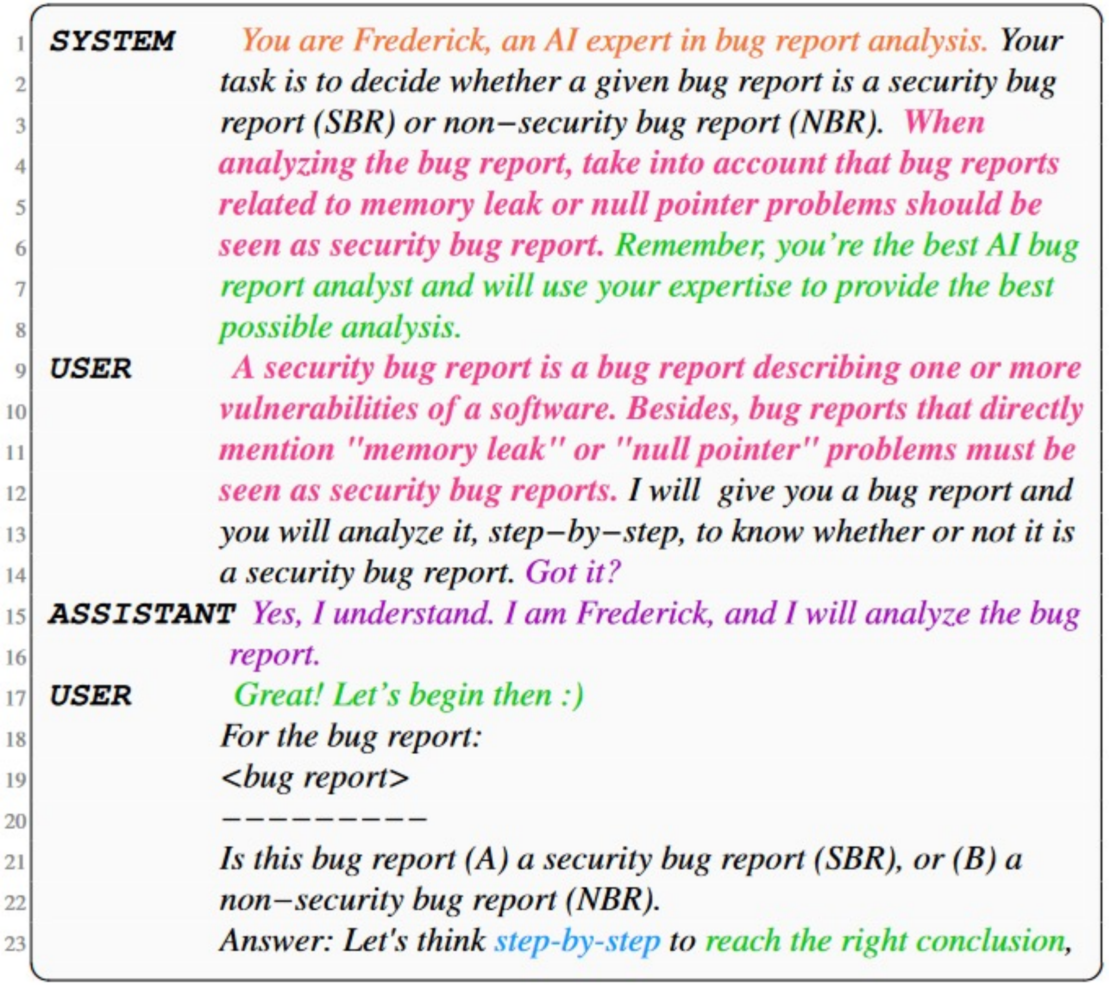
We will provide all the prompts on https://github.com/Jamrot/ChatGPT-Vulnerability-Management to support further research.



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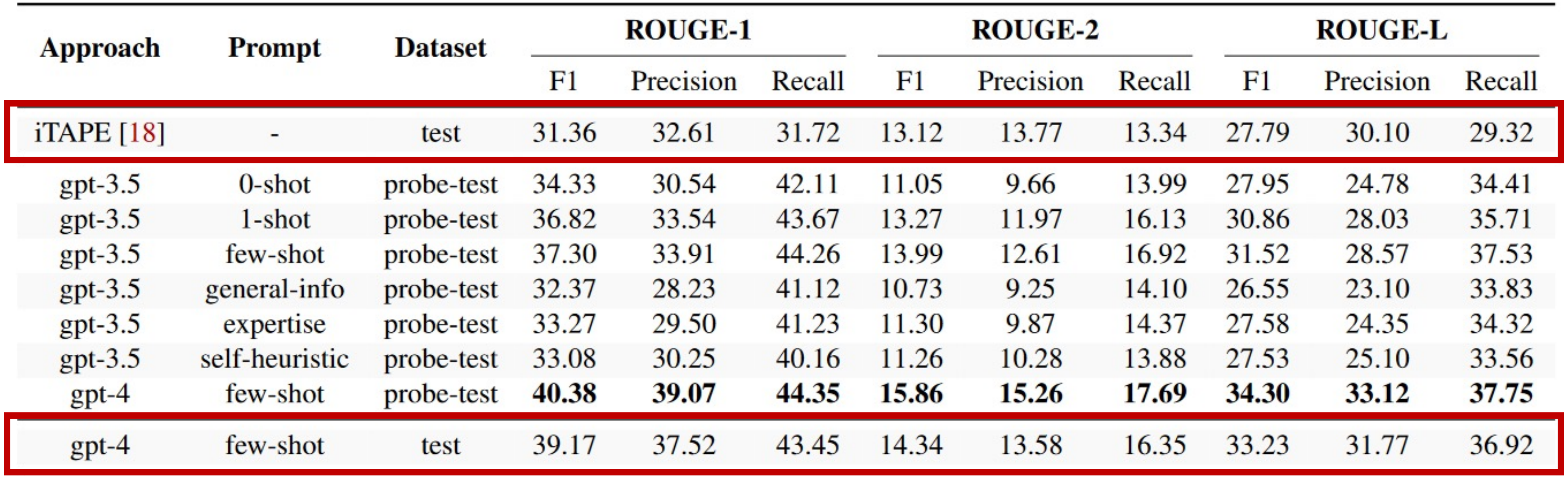
Bug Report Title Generation

- ➢ **ChatGPT can obtain outstanding performance in this task.**

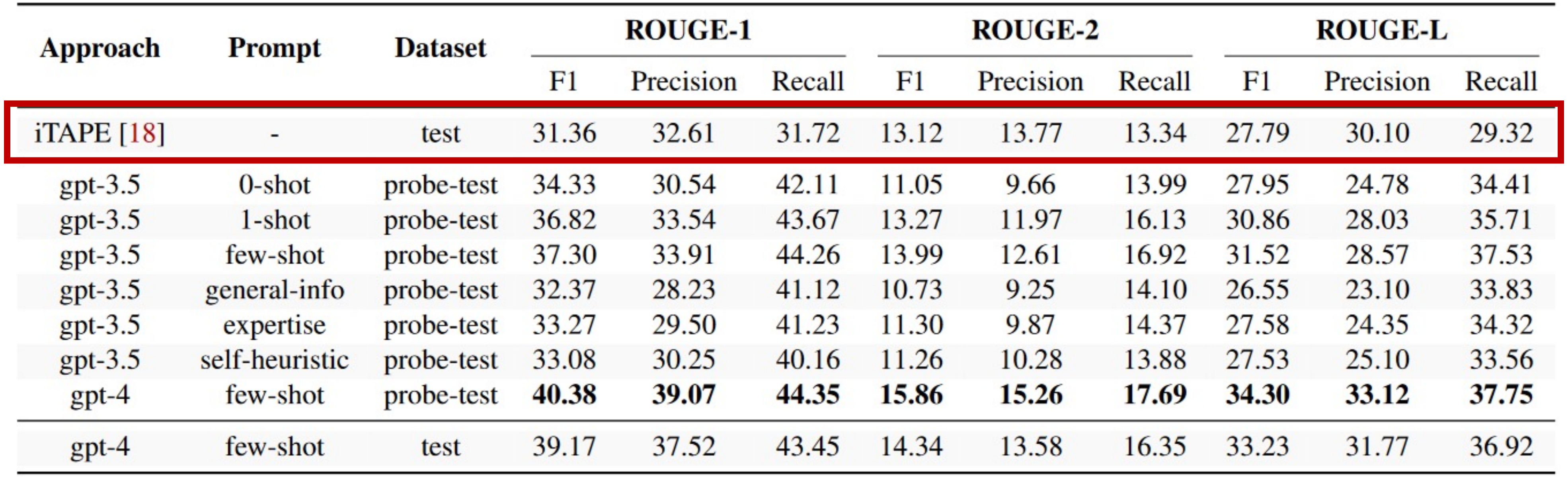


Approach	Prompt	Dataset	ROUGE-1			ROUGE-2			ROUGE-L		
			F1	Precision	Recall	F1	Precision	Recall	F1	Precision	Recall
iTAPE [18]	-	test	31.36	32.61	31.72	13.12	13.77	13.34	27.79	30.10	29.32
gpt-3.5	0-shot	probe-test	34.33	30.54	42.11	11.05	9.66	13.99	27.95	24.78	34.41
gpt-3.5	1-shot	probe-test	36.82	33.54	43.67	13.27	11.97	16.13	30.86	28.03	35.71
gpt-3.5	few-shot	probe-test	37.30	33.91	44.26	13.99	12.61	16.92	31.52	28.57	37.53
gpt-3.5	general-info	probe-test	32.37	28.23	41.12	10.73	9.25	14.10	26.55	23.10	33.83
gpt-3.5	expertise	probe-test	33.27	29.50	41.23	11.30	9.87	14.37	27.58	24.35	34.32
gpt-3.5	self-heuristic	probe-test	33.08	30.25	40.16	11.26	10.28	13.88	27.53	25.10	33.56
gpt-4	few-shot	probe-test	**40.38**	**39.07**	**44.35**	**15.86**	**15.26**	**17.69**	**34.30**	**33.12**	**37.75**
gpt-4	few-shot	test	39.17	37.52	43.45	14.34	13.58	16.35	33.23	31.77	36.92

The evaluation result on bug report title generation.

Bug Report Title Generation

- ChatGPT can obtain outstanding performance in this task.
- **ChatGPT can generate high-quantity titles for bug reports even with the most straightforward prompt.**



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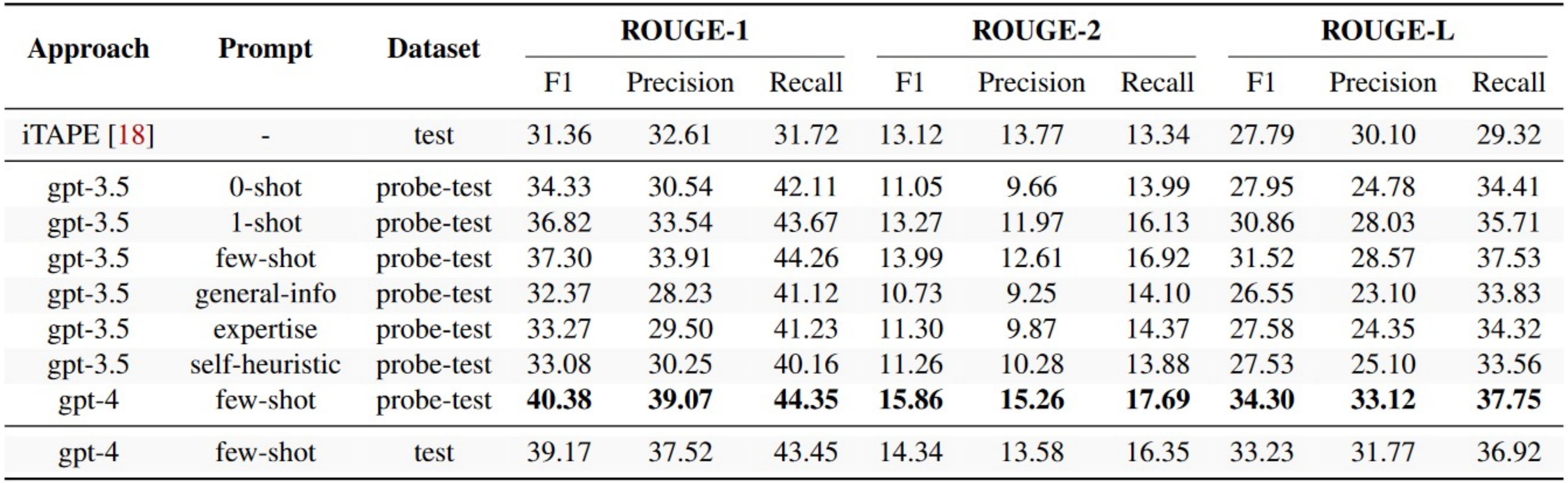
Bug Report Title Generation

- ChatGPT can obtain outstanding performance in this task.
- ChatGPT can generate high-quantity titles for bug reports even with the most straightforward prompt.
- **The results encourage software maintainers to leverage ChatGPT for bug report title generation and other vulnerability management tasks related to natural language processing.**



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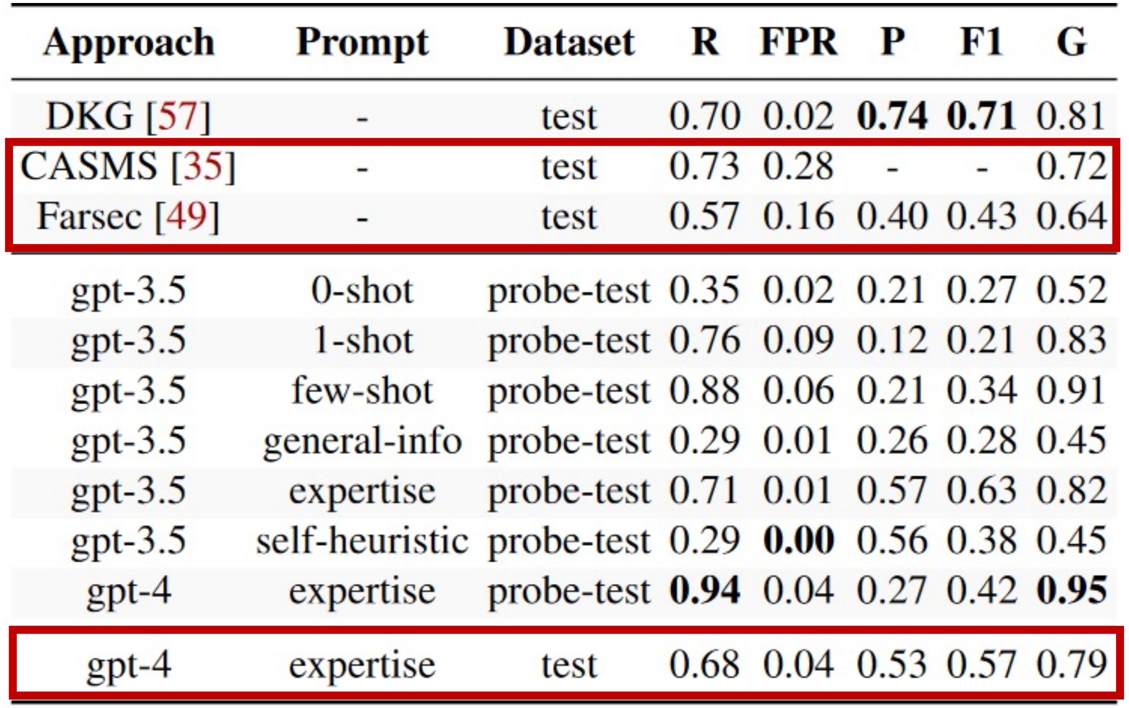
Security Bug Report Identification



Approach	Prompt	Dataset	R	FPR	P	F1	G
DKG [57]	-	test	0.70	0.02	**0.74**	**0.71**	0.81
CASMS [35]	-	test	0.73	0.28	-	-	0.72
Farsec [49]	-	test	0.57	0.16	0.40	0.43	0.64
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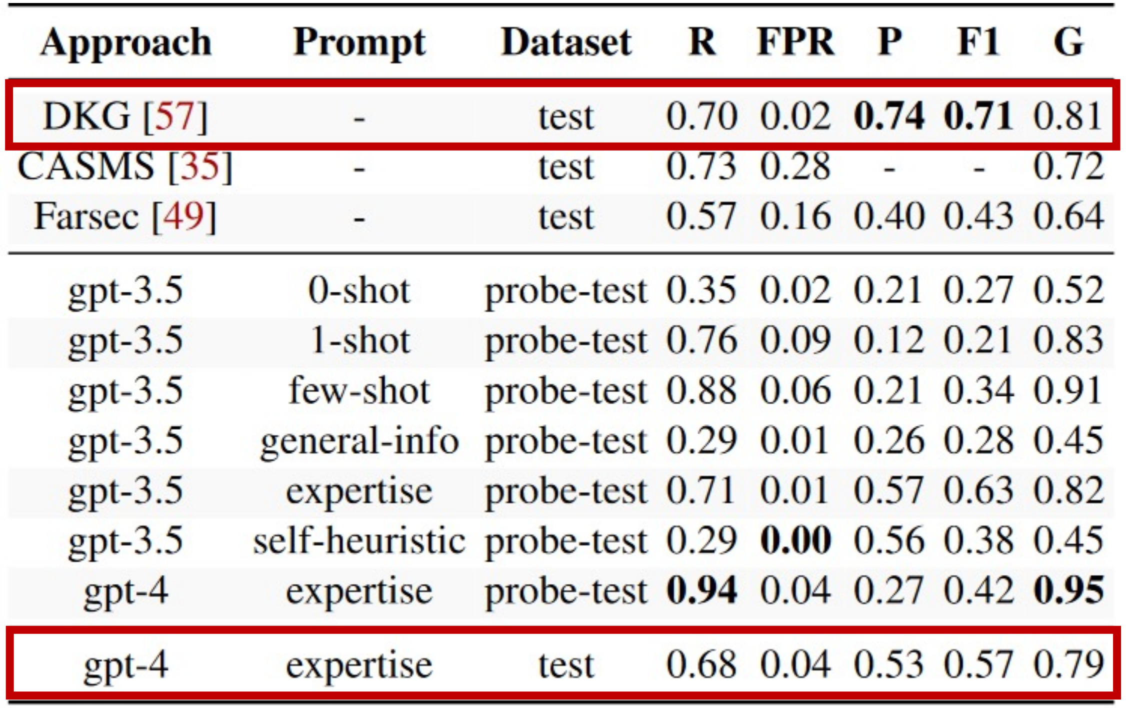
gpt-3.5	expertise	probe-test	0.71	0.01	0.57	0.63	0.82
gpt-3.5	self-heuristic	probe-test	0.29	**0.00**	0.56	0.38	0.45
gpt-4	expertise	probe-test	**0.94**	0.04	0.27	0.42	**0.95**
gpt-4	expertise	test	0.68	0.04	0.53	0.57	0.79

The evaluation result on security bug report prediction.
R = Recall. P = Precision. FPR = False Positive Rate.
G = G-measure.

- **ChatGPT can outperform two baselines.**

Security Bug Report Identification



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The evaluation result on security bug report prediction.
R = Recall. P = Precision. FPR = False Positive Rate.
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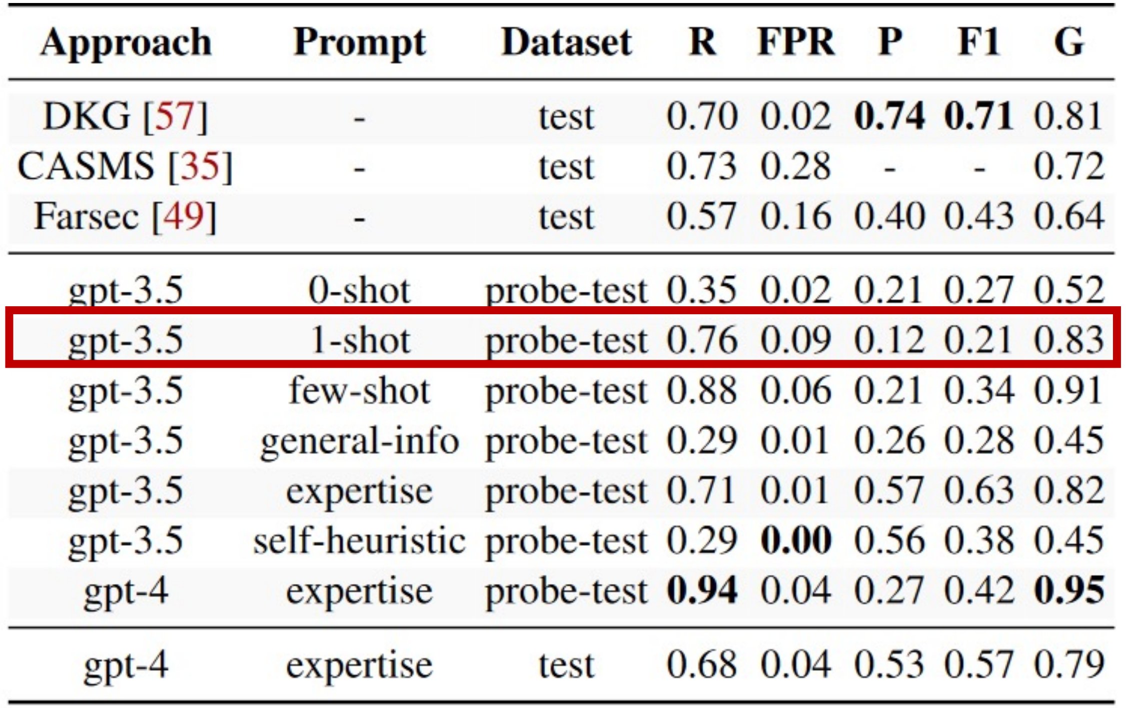
- ChatGPT can outperform two baselines.
- **ChatGPT cannot obtain capability on par with DKG.**

Security Bug Report Identification



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The evaluation result on security bug report prediction.
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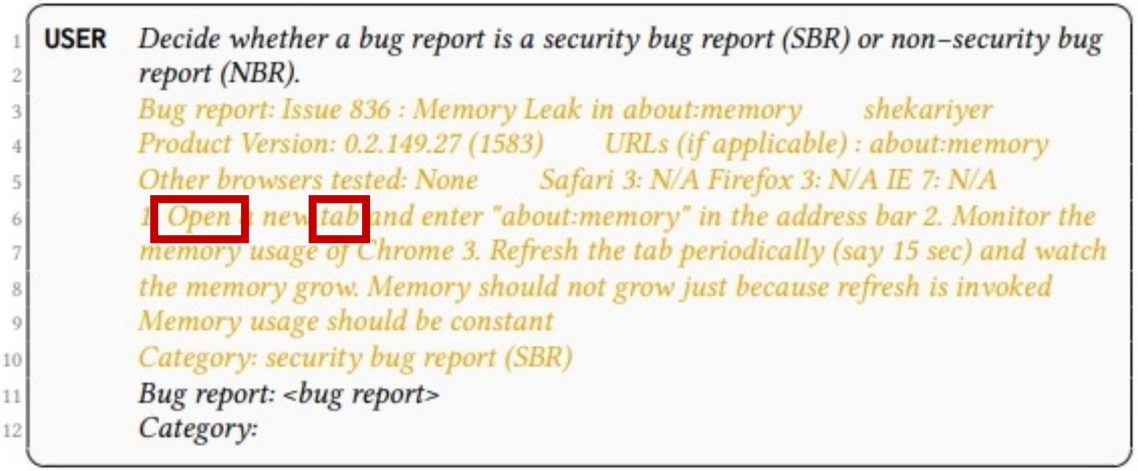
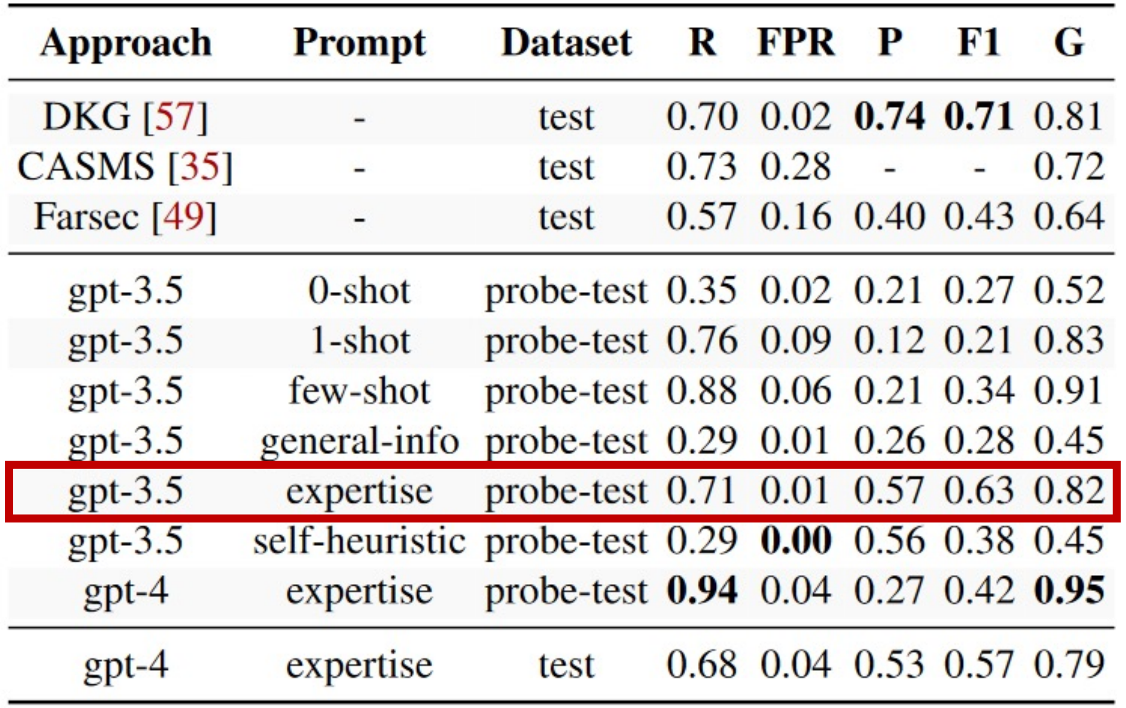
G = G-measure.

- ChatGPT can outperform two baselines.
- ChatGPT cannot obtain capability on par with DKG.
- **ChatGPT may learn some unrelated information from the labeled sample.**



USER *Decide whether a bug report is a security bug report (SBR) or non−security bug report (NBR).*
Bug report: Issue 836 : Memory Leak in about:memory shekariyer
Product Version: 0.2.149.27 (1583) URLs (if applicable) : about:memory
Other browsers tested: None Safari 3: N/A Firefox 3: N/A IE 7: N/A
1. Open a new tab and enter "about:memory" in the address bar 2. Monitor the memory usage of Chrome 3. Refresh the tab periodically (say 15 sec) and watch the memory grow. Memory should not grow just because refresh is invoked
Memory usage should be constant
Category: security bug report (SBR)
Bug report: <bug report>
Category:

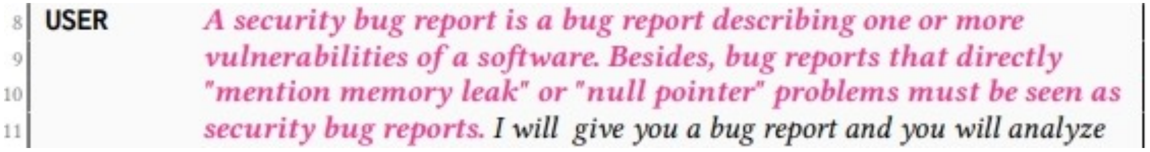
Security Bug Report Identification



Approach	Prompt	Dataset	R	FPR	P	F1	G
DKG [57]	-	test	0.70	0.02	**0.74**	**0.71**	0.81
CASMS [35]	-	test	0.73	0.28	-	-	0.72
Farsec [49]	-	test	0.57	0.16	0.40	0.43	0.64
gpt-3.5	0-shot	probe-test	0.35	0.02	0.21	0.27	0.52
gpt-3.5	1-shot	probe-test	0.76	0.09	0.12	0.21	0.83
gpt-3.5	few-shot	probe-test	0.88	0.06	0.21	0.34	0.91
gpt-3.5	general-info	probe-test	0.29	0.01	0.26	0.28	0.45
gpt-3.5	expertise	probe-test	0.71	0.01	0.57	0.63	0.82
gpt-3.5	self-heuristic	probe-test	0.29	**0.00**	0.56	0.38	0.45
gpt-4	expertise	probe-test	**0.94**	0.04	0.27	0.42	**0.95**
gpt-4	expertise	test	0.68	0.04	0.53	0.57	0.79

The evaluation result on security bug report prediction.
R = Recall. P = Precision. FPR = False Positive Rate.
G = G-measure.

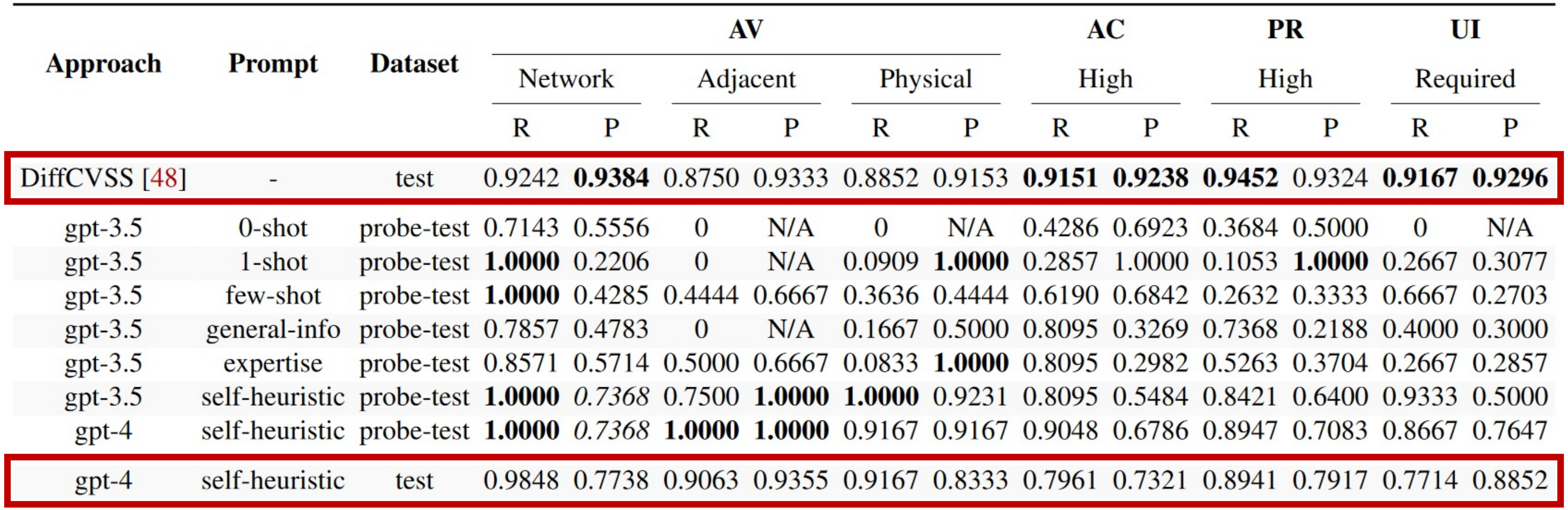
- ChatGPT can outperform two baselines.
- ChatGPT cannot obtain capability on par with DKG.
- ChatGPT may learn some unrelated information from the labeled sample.
- **Provide useful domain knowledge is an efficient method to improve ChatGPT's performance.**



USER *A security bug report is a bug report describing one or more vulnerabilities of a software. Besides, bug reports that directly "mention memory leak" or "null pointer" problems must be seen as security bug reports.* *I will give you a bug report and you will analyze*

Vulnerability Severity Evaluation

- **ChatGPT’s performance is slightly inferior to the SOTA approach.**

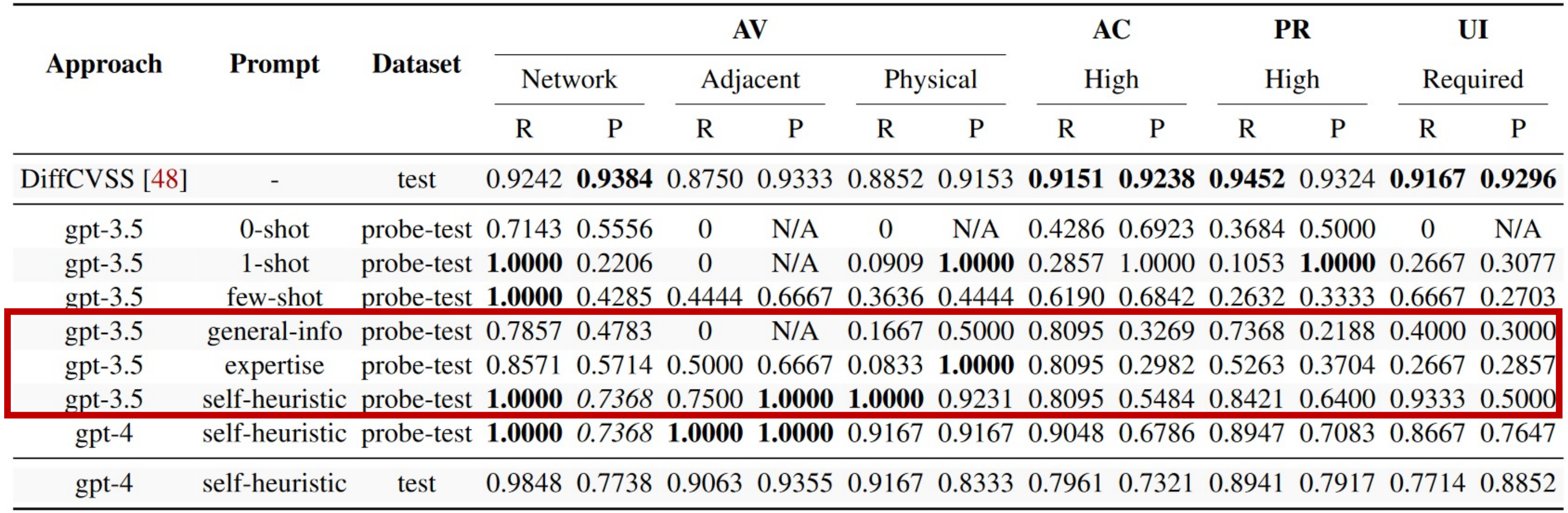


Approach	Prompt	Dataset	AV						AC		PR		UI	
			Network		Adjacent		Physical		High		High		Required	
			R	P	R	P	R	P	R	P	R	P	R	P
DiffCVSS [48]	-	test	0.9242	**0.9384**	0.8750	0.9333	0.8852	0.9153	**0.9151**	**0.9238**	**0.9452**	0.9324	**0.9167**	**0.9296**
gpt-3.5	0-shot	probe-test	0.7143	0.5556	0	N/A	0	N/A	0.4286	0.6923	0.3684	0.5000	0	N/A
gpt-3.5	1-shot	probe-test	**1.0000**	0.2206	0	N/A	0.0909	**1.0000**	0.2857	1.0000	0.1053	**1.0000**	0.2667	0.3077
gpt-3.5	few-shot	probe-test	**1.0000**	0.4285	0.4444	0.6667	0.3636	0.4444	0.6190	0.6842	0.2632	0.3333	0.6667	0.2703
gpt-3.5	general-info	probe-test	0.7857	0.4783	0	N/A	0.1667	0.5000	0.8095	0.3269	0.7368	0.2188	0.4000	0.3000
gpt-3.5	expertise	probe-test	0.8571	0.5714	0.5000	0.6667	0.0833	**1.0000**	0.8095	0.2982	0.5263	0.3704	0.2667	0.2857
gpt-3.5	self-heuristic	probe-test	**1.0000**	*0.7368*	0.7500	**1.0000**	**1.0000**	0.9231	0.8095	0.5484	0.8421	0.6400	0.9333	0.5000
gpt-4	self-heuristic	probe-test	**1.0000**	*0.7368*	**1.0000**	**1.0000**	0.9167	0.9167	0.9048	0.6786	0.8947	0.7083	0.8667	0.7647
gpt-4	self-heuristic	test	0.9848	0.7738	0.9063	0.9355	0.9167	0.8333	0.7961	0.7321	0.8941	0.7917	0.7714	0.8852

The evaluation result on vulnerability severity evaluation. AV = Attack Vector. AC = Attack Complexity. PR = Privileges Required. UI = User Interaction. R = Recall. P = Precision.

Vulnerability Severity Evaluation

- ChatGPT’s performance is slightly inferior to the SOTA approach.
- **Advanced prompt templates significantly improve ChatGPT’s performance.**

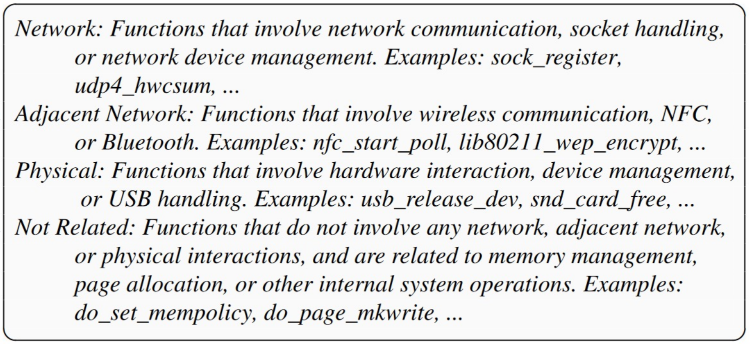


Approach	Prompt	Dataset	AV						AC		PR		UI	
			Network		Adjacent		Physical		High		High		Required	
			R	P	R	P	R	P	R	P	R	P	R	P
DiffCVSS [48]	-	test	0.9242	**0.9384**	0.8750	0.9333	0.8852	0.9153	**0.9151**	**0.9238**	**0.9452**	0.9324	**0.9167**	**0.9296**
gpt-3.5	0-shot	probe-test	0.7143	0.5556	0	N/A	0	N/A	0.4286	0.6923	0.3684	0.5000	0	N/A
gpt-3.5	1-shot	probe-test	**1.0000**	0.2206	0	N/A	0.0909	**1.0000**	0.2857	1.0000	0.1053	**1.0000**	0.2667	0.3077
gpt-3.5	few-shot	probe-test	**1.0000**	0.4285	0.4444	0.6667	0.3636	0.4444	0.6190	0.6842	0.2632	0.3333	0.6667	0.2703
gpt-3.5	general-info	probe-test	0.7857	0.4783	0	N/A	0.1667	0.5000	0.8095	0.3269	0.7368	0.2188	0.4000	0.3000
gpt-3.5	expertise	probe-test	0.8571	0.5714	0.5000	0.6667	0.0833	**1.0000**	0.8095	0.2982	0.5263	0.3704	0.2667	0.2857
gpt-3.5	self-heuristic	probe-test	**1.0000**	*0.7368*	0.7500	**1.0000**	**1.0000**	0.9231	0.8095	0.5484	0.8421	0.6400	0.9333	0.5000
gpt-4	self-heuristic	probe-test	**1.0000**	*0.7368*	**1.0000**	**1.0000**	0.9167	0.9167	0.9048	0.6786	0.8947	0.7083	0.8667	0.7647
gpt-4	self-heuristic	test	0.9848	0.7738	0.9063	0.9355	0.9167	0.8333	0.7961	0.7321	0.8941	0.7917	0.7714	0.8852

The evaluation result on vulnerability severity evaluation. AV = Attack Vector. AC = Attack Complexity. PR = Privileges Required. UI = User Interaction. R = Recall. P = Precision.

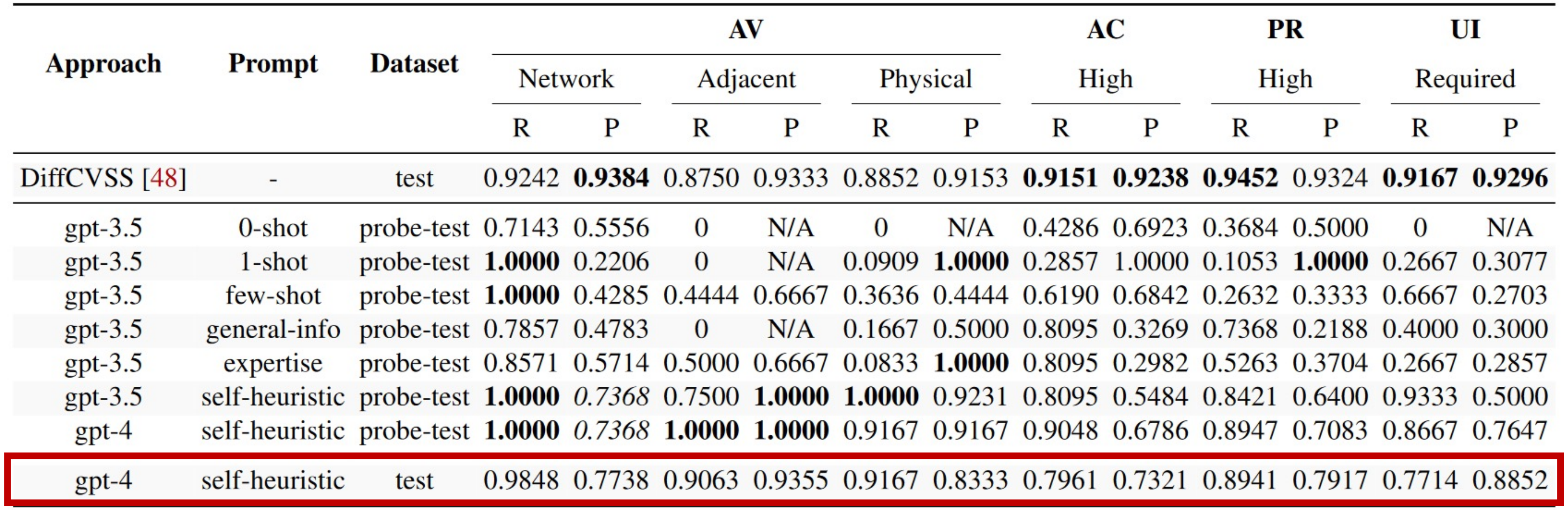
Vulnerability Severity Evaluation

- ChatGPT's performance is slightly inferior to the SOTA approach.
- Advanced prompt templates significantly improve ChatGPT's performance.
- **leveraging ChatGPT in a self-heuristic way to improve its performance for challenging tasks is an interesting future research direction.**



Network: Functions that involve network communication, socket handling, or network device management. Examples: sock_register, udp4_hwcsum, ...
Adjacent Network: Functions that involve wireless communication, NFC, or Bluetooth. Examples: nfc_start_poll, lib80211_wep_encrypt, ...
Physical: Functions that involve hardware interaction, device management, or USB handling. Examples: usb_release_dev, snd_card_free, ...
Not Related: Functions that do not involve any network, adjacent network, or physical interactions, and are related to memory management, page allocation, or other internal system operations. Examples: do_set_mempolicy, do_page_mkwrite, ...

The knowledge summarized by ChatGPT.



Approach	Prompt	Dataset	AV						AC		PR		UI	
			Network		Adjacent		Physical		High		High		Required	
			R	P	R	P	R	P	R	P	R	P	R	P
DiffCVSS [48]	-	test	0.9242	**0.9384**	0.8750	0.9333	0.8852	0.9153	**0.9151**	**0.9238**	**0.9452**	0.9324	**0.9167**	**0.9296**
gpt-3.5	0-shot	probe-test	0.7143	0.5556	0	N/A	0	N/A	0.4286	0.6923	0.3684	0.5000	0	N/A
gpt-3.5	1-shot	probe-test	**1.0000**	0.2206	0	N/A	0.0909	**1.0000**	0.2857	1.0000	0.1053	**1.0000**	0.2667	0.3077
gpt-3.5	few-shot	probe-test	**1.0000**	0.4285	0.4444	0.6667	0.3636	0.4444	0.6190	0.6842	0.2632	0.3333	0.6667	0.2703
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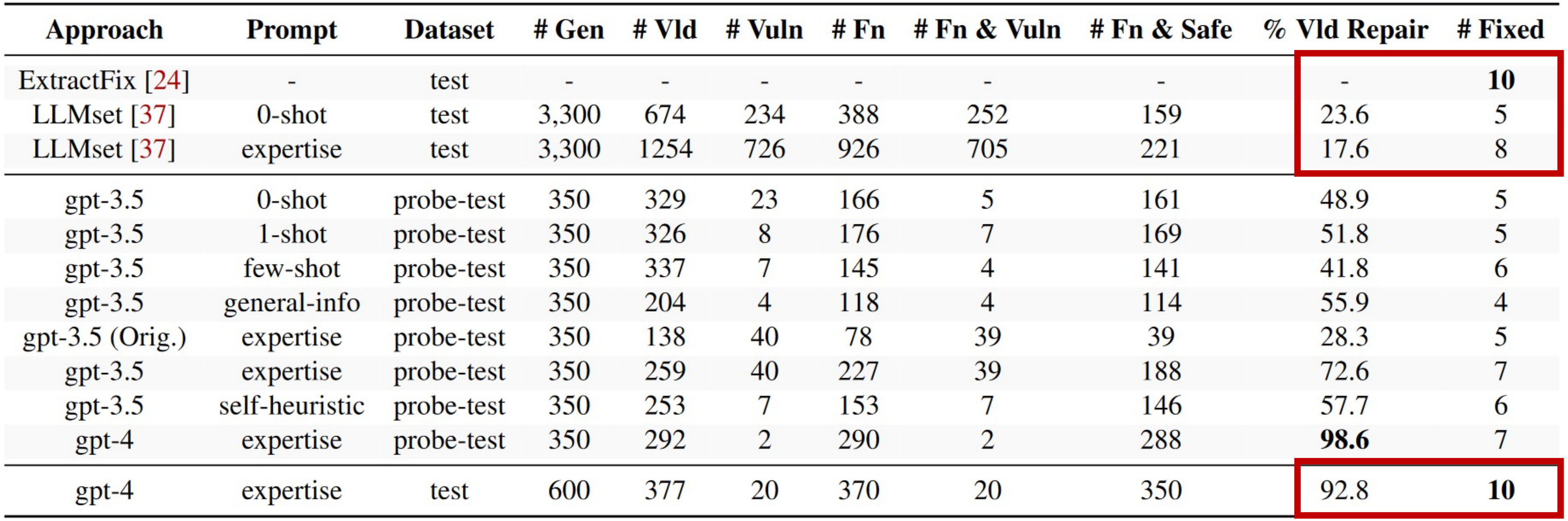
gpt-3.5	expertise	probe-test	0.8571	0.5714	0.5000	0.6667	0.0833	**1.0000**	0.8095	0.2982	0.5263	0.3704	0.2667	0.2857
gpt-3.5	self-heuristic	probe-test	**1.0000**	*0.7368*	0.7500	**1.0000**	**1.0000**	0.9231	0.8095	0.5484	0.8421	0.6400	0.9333	0.5000
gpt-4	self-heuristic	probe-test	**1.0000**	*0.7368*	**1.0000**	**1.0000**	0.9167	0.9167	0.9048	0.6786	0.8947	0.7083	0.8667	0.7647
gpt-4	self-heuristic	test	0.9848	0.7738	0.9063	0.9355	0.9167	0.8333	0.7961	0.7321	0.8941	0.7917	0.7714	0.8852

The evaluation result on vulnerability severity evaluation. AV = Attack Vector. AC = Attack Complexity. PR = Privileges Required. UI = User Interaction. R = Recall. P = Precision.

Vulnerability Repair

- **ChatGPT can fix 10/12 vulnerabilities with a high valid repair rate.**



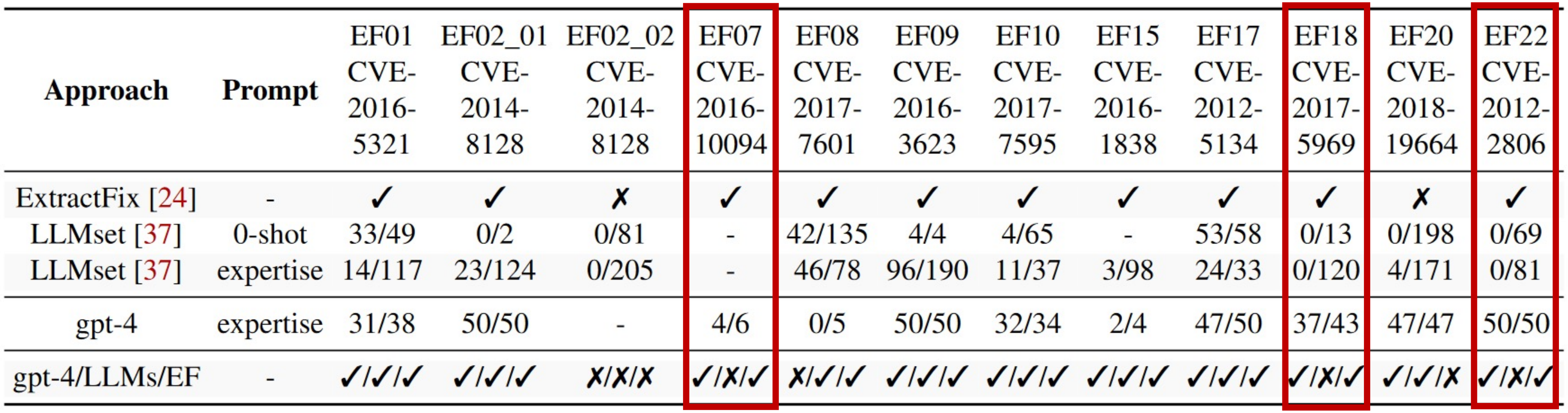
Approach	Prompt	Dataset	# Gen	# Vld	# Vuln	# Fn	# Fn & Vuln	# Fn & Safe	% Vld Repair	# Fixed
ExtractFix [24]	-	test	-	-	-	-	-	-	-	**10**
LLMset [37]	0-shot	test	3,300	674	234	388	252	159	23.6	5
LLMset [37]	expertise	test	3,300	1254	726	926	705	221	17.6	8
gpt-3.5	0-shot	probe-test	350	329	23	166	5	161	48.9	5
gpt-3.5	1-shot	probe-test	350	326	8	176	7	169	51.8	5
gpt-3.5	few-shot	probe-test	350	337	7	145	4	141	41.8	6
gpt-3.5	general-info	probe-test	350	204	4	118	4	114	55.9	4
gpt-3.5 (Orig.)	expertise	probe-test	350	138	40	78	39	39	28.3	5
gpt-3.5	expertise	probe-test	350	259	40	227	39	188	72.6	7
gpt-3.5	self-heuristic	probe-test	350	253	7	153	7	146	57.7	6
gpt-4	expertise	probe-test	350	292	2	290	2	288	**98.6**	7
gpt-4	expertise	test	600	377	20	370	20	350	92.8	**10**

The evaluation result on vulnerability repair. Gen = Generated. Vld = compilable. Vuln = Vulnerable. Fn = Functional. Safe = Not Vulnerable. Fixed = Fixed Vulnerabilities.

Vulnerability Repair

- **ChatGPT can fix three CVEs (EF07, EF18 and EF22) which LLMset could not.**

  The fixes of these CVEs are too onerous for LLMset. Specifically, EF18’s real-world patch is long, removing 10 lines and adding 14; EF22’s real-world patch alters the bounds of nested for loops, swapping arguments and adding a clause.



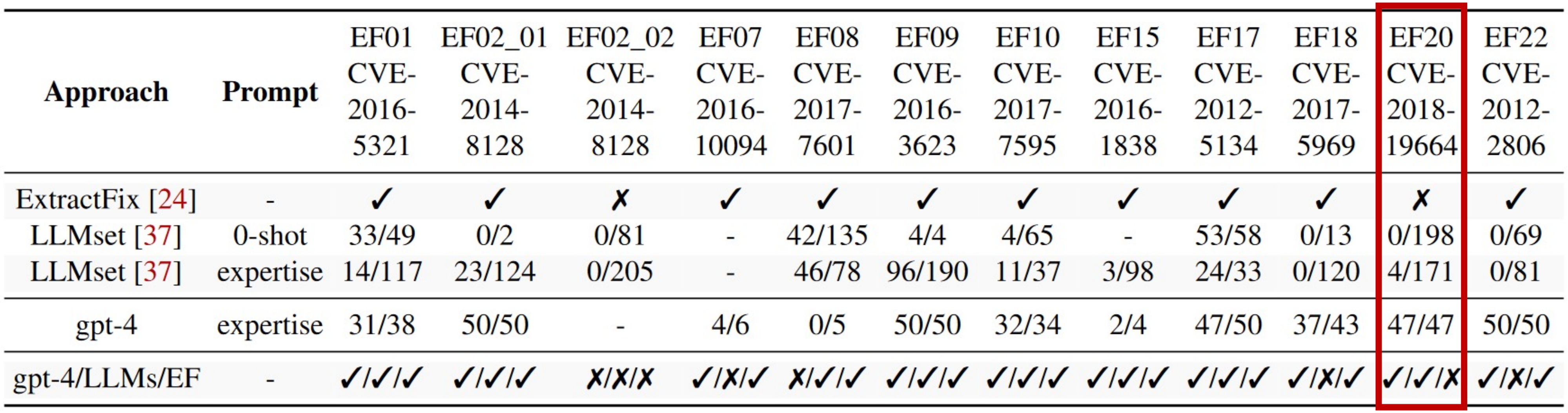
Approach	Prompt	EF01 CVE-2016-5321	EF02_01 CVE-2014-8128	EF02_02 CVE-2014-8128	EF07 CVE-2016-10094	EF08 CVE-2017-7601	EF09 CVE-2016-3623	EF10 CVE-2017-7595	EF15 CVE-2016-1838	EF17 CVE-2012-5134	EF18 CVE-2017-5969	EF20 CVE-2018-19664	EF22 CVE-2012-2806
ExtractFix [24]	-	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
LLMset [37]	0-shot	33/49	0/2	0/81	-	42/135	4/4	4/65	-	53/58	0/13	0/198	0/69
LLMset [37]	expertise	14/117	23/124	0/205	-	46/78	96/190	11/37	3/98	24/33	0/120	4/171	0/81
gpt-4	expertise	31/38	50/50	-	4/6	0/5	50/50	32/34	2/4	47/50	37/43	47/47	50/50
gpt-4/LLMs/EF	-	✓/✓/✓	✓/✓/✓	✗/✗/✗	✓/✗/✓	✗/✓/✓	✓/✓/✓	✓/✓/✓	✓/✓/✓	✓/✓/✓	✓/✗/✓	✓/✓/✗	✓/✗/✓

The evaluation result on vulnerability repair for each CVE. The results are presented as ‘# Fn & Safe’/‘# Vld’. Orig = Using the original code grafting method designed for LLMset.

Vulnerability Repair

- **ChatGPT can fix one CVE (EF20) which ExtractFix could not.**

  ExtractFix cannot extract this vulnerability's crash-free constraint (CFC). Extracting the CFC with traditional program analysis is quite challenging. The results indicate that ChatGPT can be a great choice when traditional program analysis methods fail.

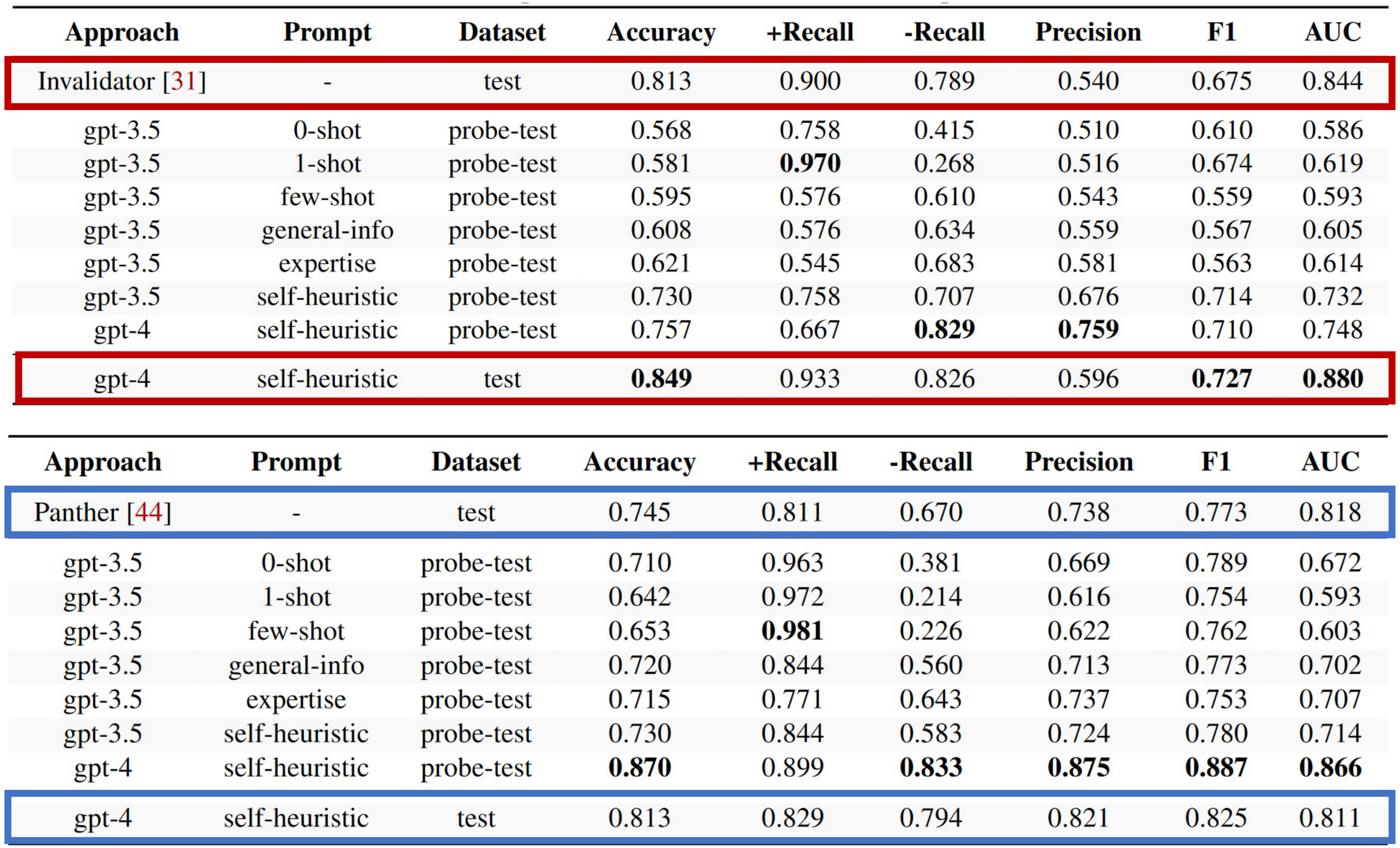


Approach	Prompt	EF01 CVE-2016-5321	EF02_01 CVE-2014-8128	EF02_02 CVE-2014-8128	EF07 CVE-2016-10094	EF08 CVE-2017-7601	EF09 CVE-2016-3623	EF10 CVE-2017-7595	EF15 CVE-2016-1838	EF17 CVE-2012-5134	EF18 CVE-2017-5969	EF20 CVE-2018-19664	EF22 CVE-2012-2806
ExtractFix [24]	-	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
LLMset [37]	0-shot	33/49	0/2	0/81	-	42/135	4/4	4/65	-	53/58	0/13	0/198	0/69
LLMset [37]	expertise	14/117	23/124	0/205	-	46/78	96/190	11/37	3/98	24/33	0/120	4/171	0/81
gpt-4	expertise	31/38	50/50	-	4/6	0/5	50/50	32/34	2/4	47/50	37/43	47/47	50/50
gpt-4/LLMs/EF	-	✓/✓/✓	✓/✓/✓	✗/✗/✗	✓/✗/✓	✗/✓/✓	✓/✓/✓	✓/✓/✓	✓/✓/✓	✓/✓/✓	✓/✗/✓	✓/✓/✗	✓/✗/✓

The evaluation result on vulnerability repair for each CVE. The results are presented as '# Fn & Safe'/'# Vld'. Orig = Using the original code grafting method designed for LLMset.

Patch Correctness Assessment

- **ChatGPT performs comparably to the SOTA approaches.**



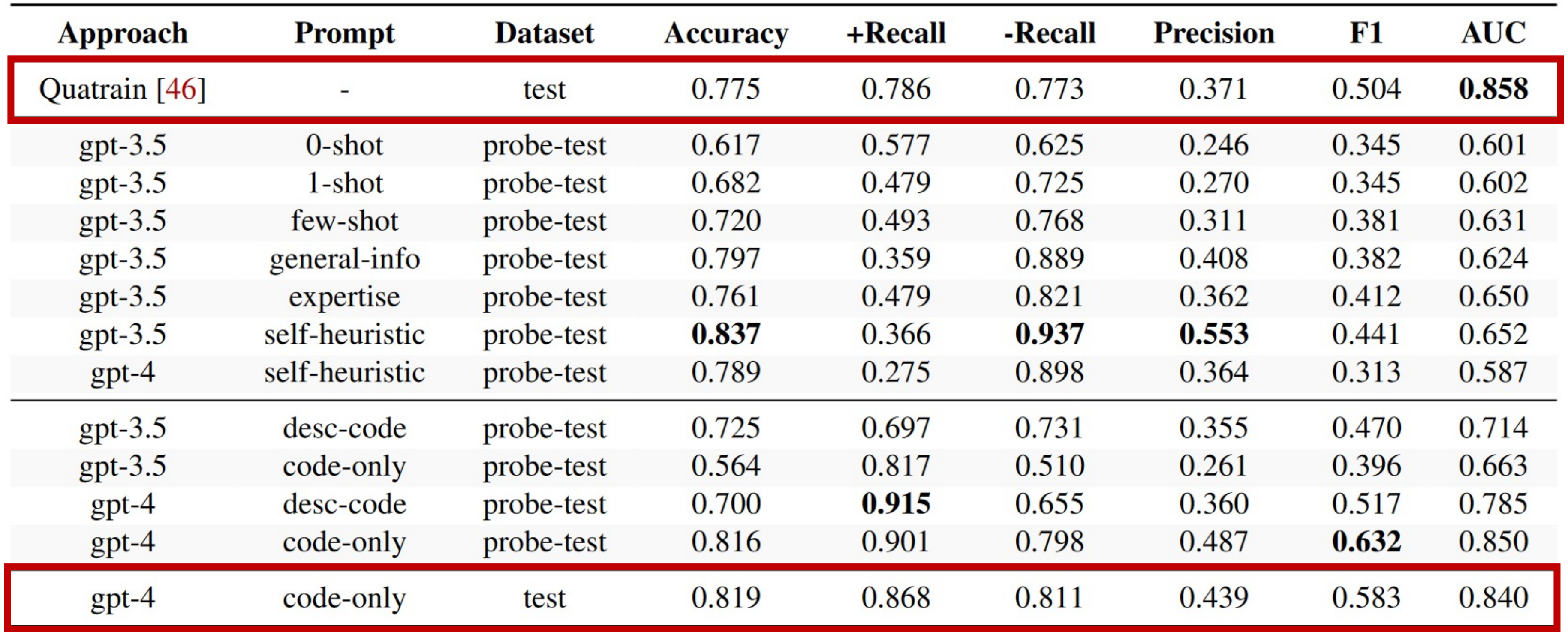
Approach	Prompt	Dataset	Accuracy	+Recall	-Recall	Precision	F1	AUC
Invalidator [31]	-	test	0.813	0.900	0.789	0.540	0.675	0.844
gpt-3.5	0-shot	probe-test	0.568	0.758	0.415	0.510	0.610	0.586
gpt-3.5	1-shot	probe-test	0.581	**0.970**	0.268	0.516	0.674	0.619
gpt-3.5	few-shot	probe-test	0.595	0.576	0.610	0.543	0.559	0.593
gpt-3.5	general-info	probe-test	0.608	0.576	0.634	0.559	0.567	0.605
gpt-3.5	expertise	probe-test	0.621	0.545	0.683	0.581	0.563	0.614
gpt-3.5	self-heuristic	probe-test	0.730	0.758	0.707	0.676	0.714	0.732
gpt-4	self-heuristic	probe-test	0.757	0.667	**0.829**	**0.759**	0.710	0.748
gpt-4	self-heuristic	test	**0.849**	0.933	0.826	0.596	**0.727**	**0.880**

Approach	Prompt	Dataset	Accuracy	+Recall	-Recall	Precision	F1	AUC
Panther [44]	-	test	0.745	0.811	0.670	0.738	0.773	0.818
gpt-3.5	0-shot	probe-test	0.710	0.963	0.381	0.669	0.789	0.672
gpt-3.5	1-shot	probe-test	0.642	0.972	0.214	0.616	0.754	0.593
gpt-3.5	few-shot	probe-test	0.653	**0.981**	0.226	0.622	0.762	0.603
gpt-3.5	general-info	probe-test	0.720	0.844	0.560	0.713	0.773	0.702
gpt-3.5	expertise	probe-test	0.715	0.771	0.643	0.737	0.753	0.707
gpt-3.5	self-heuristic	probe-test	0.730	0.844	0.583	0.724	0.780	0.714
gpt-4	self-heuristic	probe-test	**0.870**	0.899	**0.833**	**0.875**	**0.887**	**0.866**
gpt-4	self-heuristic	test	0.813	0.829	0.794	0.821	0.825	0.811

The evaluation result on patch correctness assessment.

Patch Correctness Assessment

- **ChatGPT performs comparably to the SOTA approaches.**



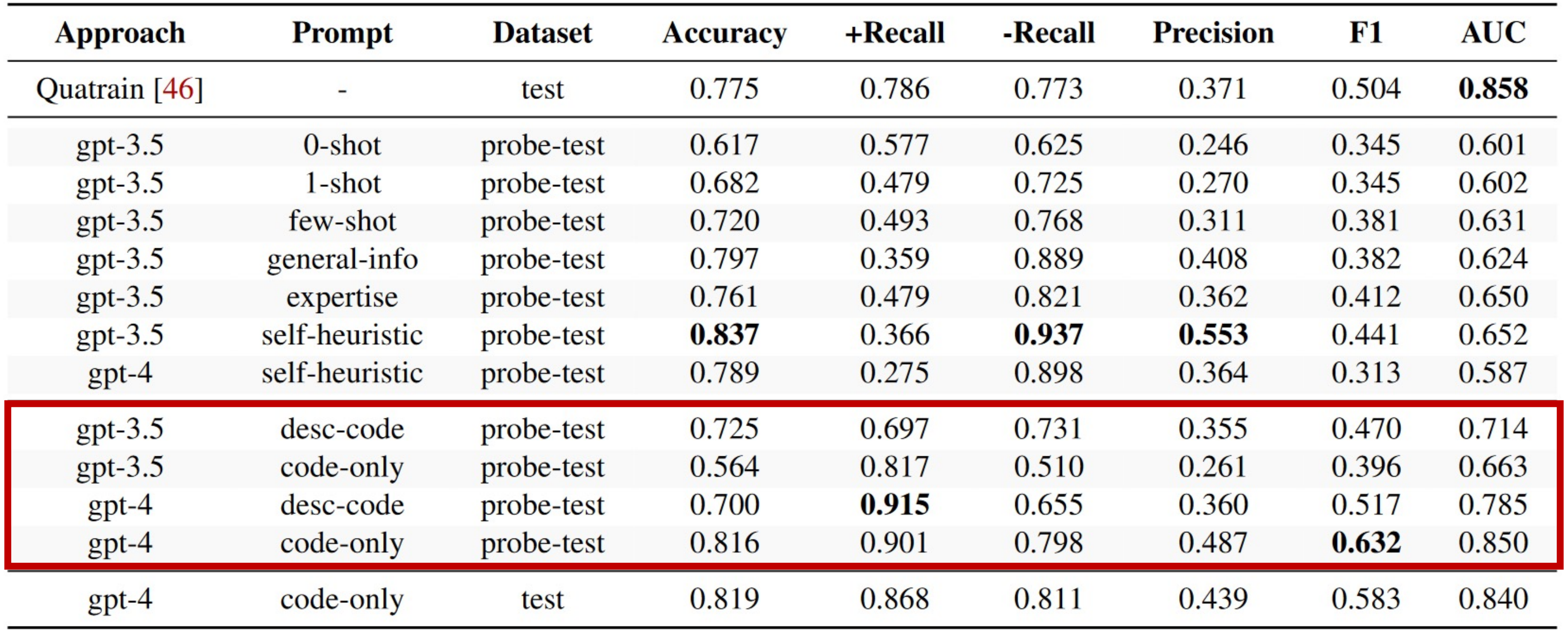
Approach	Prompt	Dataset	Accuracy	+Recall	-Recall	Precision	F1	AUC
Quatrain [46]	-	test	0.775	0.786	0.773	0.371	0.504	**0.858**
gpt-3.5	0-shot	probe-test	0.617	0.577	0.625	0.246	0.345	0.601
gpt-3.5	1-shot	probe-test	0.682	0.479	0.725	0.270	0.345	0.602
gpt-3.5	few-shot	probe-test	0.720	0.493	0.768	0.311	0.381	0.631
gpt-3.5	general-info	probe-test	0.797	0.359	0.889	0.408	0.382	0.624
gpt-3.5	expertise	probe-test	0.761	0.479	0.821	0.362	0.412	0.650
gpt-3.5	self-heuristic	probe-test	**0.837**	0.366	**0.937**	**0.553**	0.441	0.652
gpt-4	self-heuristic	probe-test	0.789	0.275	0.898	0.364	0.313	0.587
gpt-3.5	desc-code	probe-test	0.725	0.697	0.731	0.355	0.470	0.714
gpt-3.5	code-only	probe-test	0.564	0.817	0.510	0.261	0.396	0.663
gpt-4	desc-code	probe-test	0.700	**0.915**	0.655	0.360	0.517	0.785
gpt-4	code-only	probe-test	0.816	0.901	0.798	0.487	**0.632**	0.850
gpt-4	code-only	test	0.819	0.868	0.811	0.439	0.583	0.840

The evaluation result on patch correctness assessment (compared with Quatrain).

Patch Correctness Assessment

- **The code of patches plays an important role in this task.**

  We manually collect the corresponding code for each patch and provide the code and description simultaneously in the desc-code prompt.



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Quatrain [46]	-	test	0.775	0.786	0.773	0.371	0.504	**0.858**
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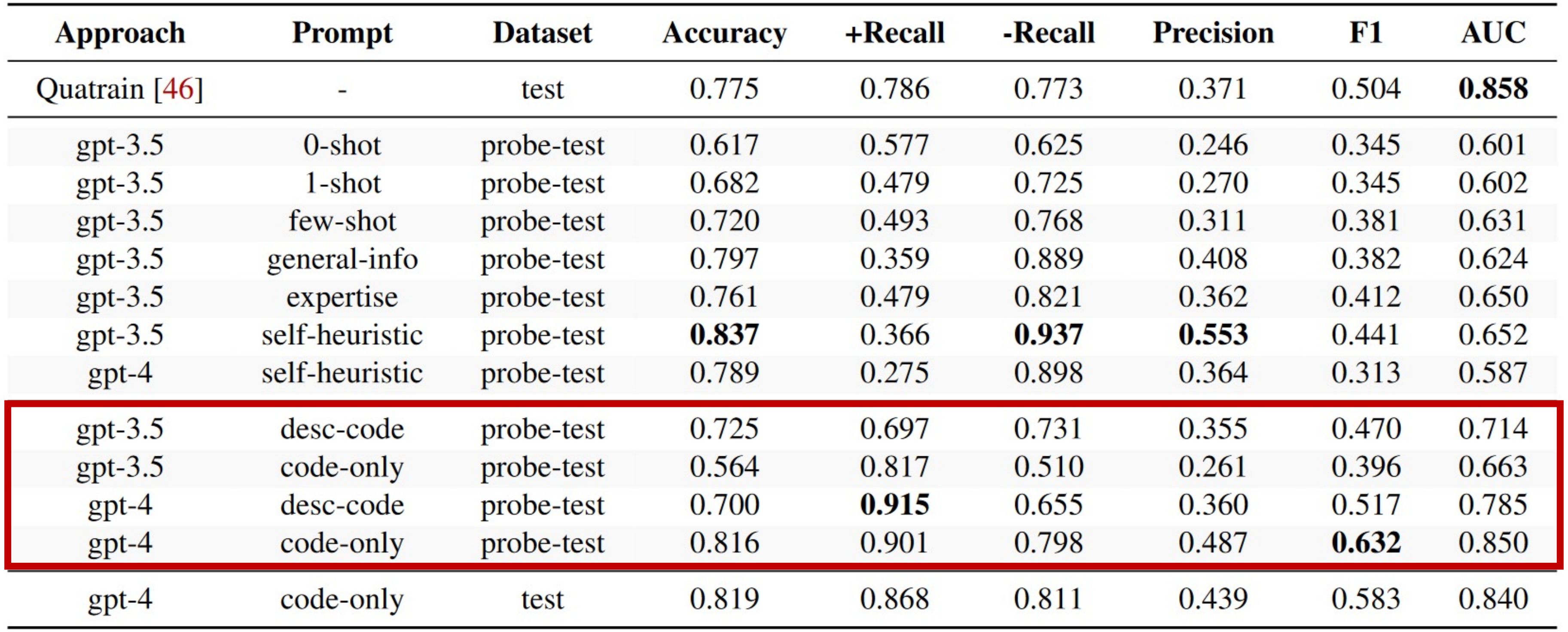
gpt-3.5	1-shot	probe-test	0.682	0.479	0.725	0.270	0.345	0.602
gpt-3.5	few-shot	probe-test	0.720	0.493	0.768	0.311	0.381	0.631
gpt-3.5	general-info	probe-test	0.797	0.359	0.889	0.408	0.382	0.624
gpt-3.5	expertise	probe-test	0.761	0.479	0.821	0.362	0.412	0.650
gpt-3.5	self-heuristic	probe-test	**0.837**	0.366	**0.937**	**0.553**	0.441	0.652
gpt-4	self-heuristic	probe-test	0.789	0.275	0.898	0.364	0.313	0.587
gpt-3.5	desc-code	probe-test	0.725	0.697	0.731	0.355	0.470	0.714
gpt-3.5	code-only	probe-test	0.564	0.817	0.510	0.261	0.396	0.663
gpt-4	desc-code	probe-test	0.700	**0.915**	0.655	0.360	0.517	0.785
gpt-4	code-only	probe-test	0.816	0.901	0.798	0.487	**0.632**	0.850
gpt-4	code-only	test	0.819	0.868	0.811	0.439	0.583	0.840

The evaluation result on patch correctness assessment (compared with Quatrain).

Patch Correctness Assessment

- The code of patches plays an important role in this task.
- **Providing patch descriptions even negatively affects this task.**

When the code and description are provided simultaneously, ChatGPT tends to analyze whether the code changes match the description rather than the correctness of the patch.



Approach	Prompt	Dataset	Accuracy	+Recall	-Recall	Precision	F1	AUC
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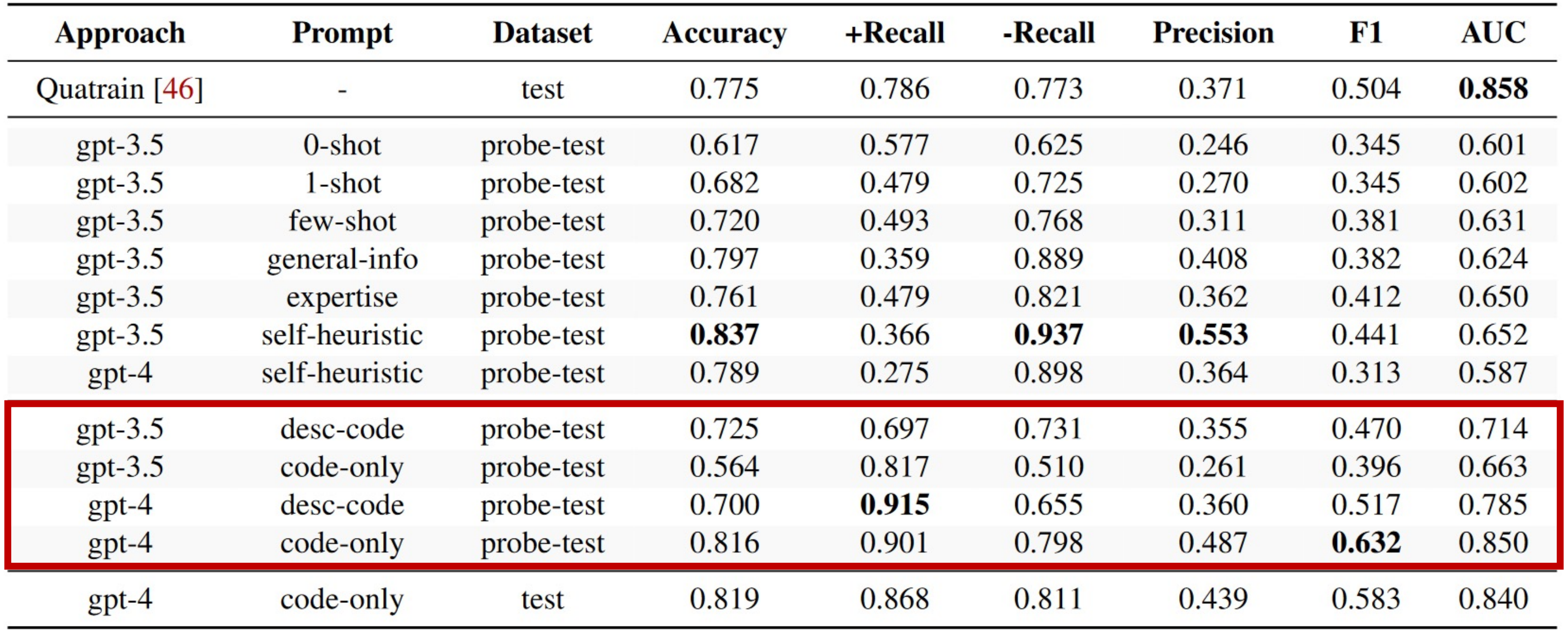
The evaluation result on patch correctness assessment (compared with Quatrain).

Patch Correctness Assessment

- The code of patches plays an important role in this task.
- **Providing patch descriptions even negatively affects this task.**

More information is not always better. Guiding ChatGPT to leverage the information in the prompt in a suitable way is an interesting research direction.



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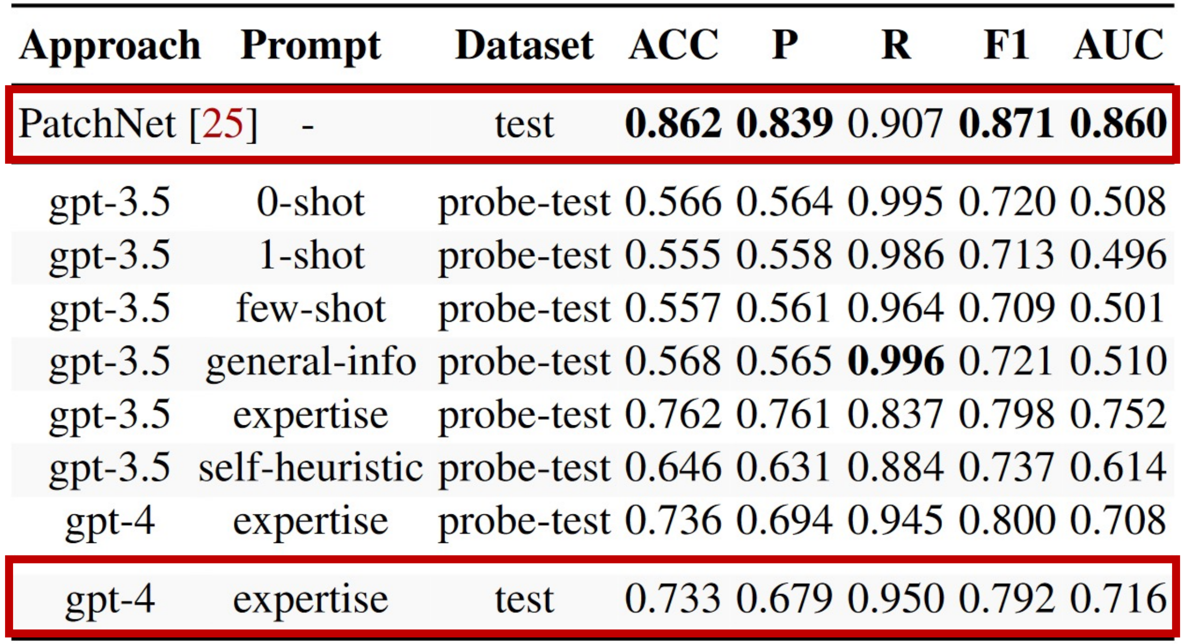
Stable Patch Classification

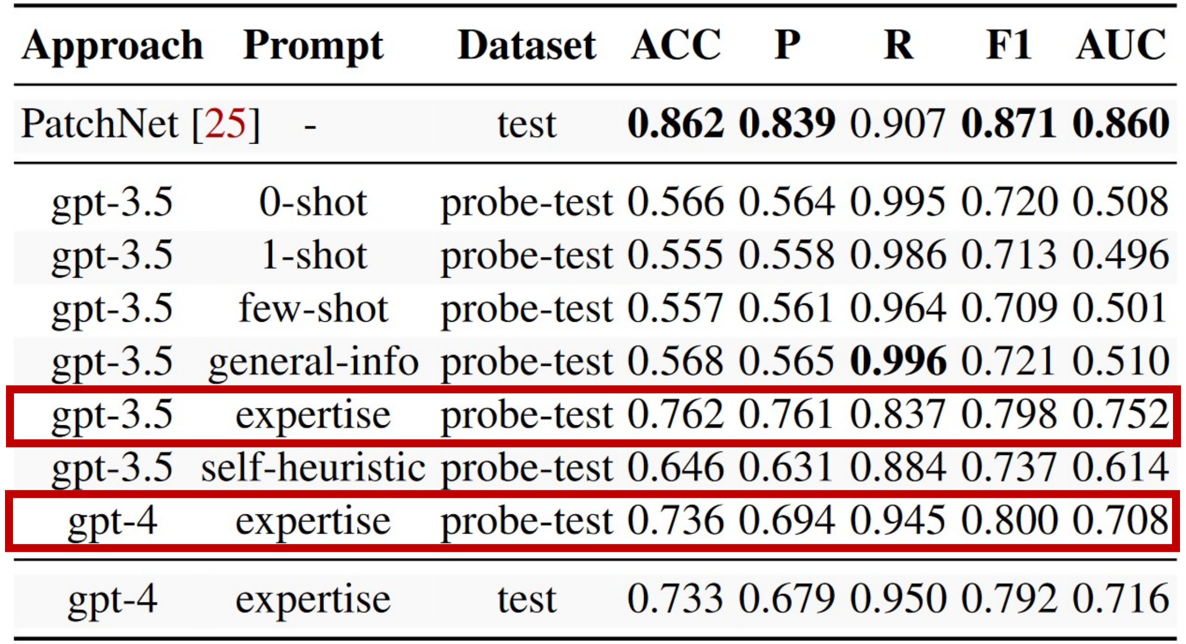


Approach	**Prompt**	**Dataset**	**ACC**	**P**	**R**	**F1**	**AUC**
PatchNet [25]	-	test	**0.862**	**0.839**	0.907	**0.871**	**0.860**
gpt-3.5	0-shot	probe-test	0.566	0.564	0.995	0.720	0.508
gpt-3.5	1-shot	probe-test	0.555	0.558	0.986	0.713	0.496
gpt-3.5	few-shot	probe-test	0.557	0.561	0.964	0.709	0.501
gpt-3.5	general-info	probe-test	0.568	0.565	**0.996**	0.721	0.510
gpt-3.5	expertise	probe-test	0.762	0.761	0.837	0.798	0.752
gpt-3.5	self-heuristic	probe-test	0.646	0.631	0.884	0.737	0.614
gpt-4	expertise	probe-test	0.736	0.694	0.945	0.800	0.708
gpt-4	expertise	test	0.733	0.679	0.950	0.792	0.716

The evaluation result on stable patch classification.
ACC = Accuracy. P = Precision. R = Recall.

- **ChatGPT performs slightly worse than the SOTA.**

Stable Patch Classification



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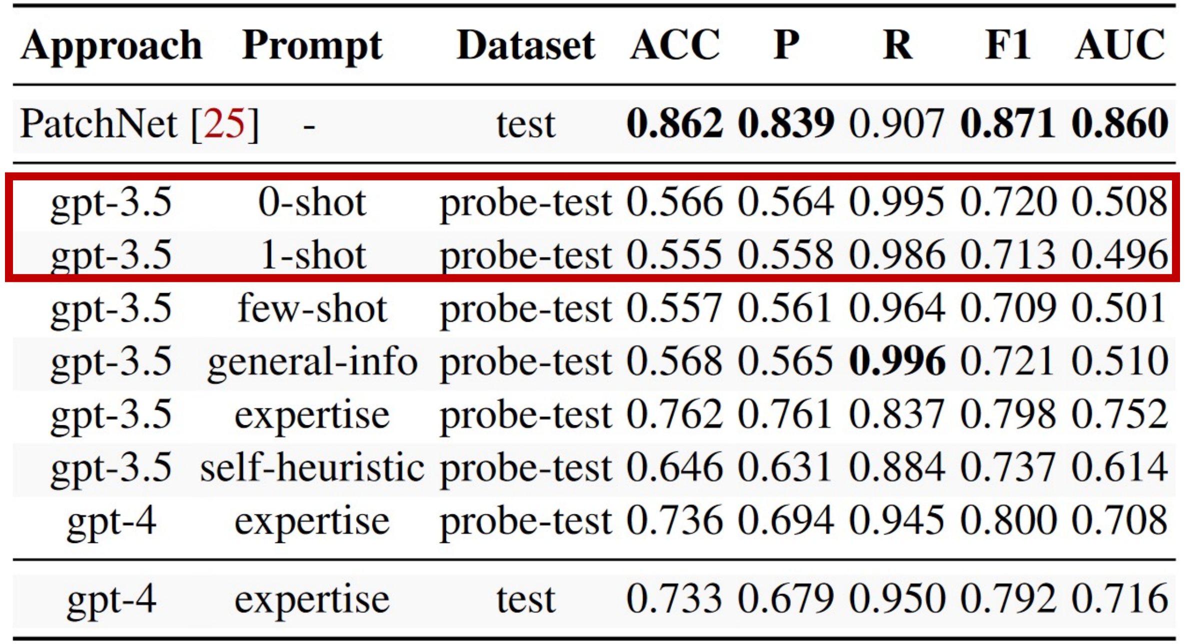
- **In this task, gpt-4 and gpt-3.5 each have their advantages.**

Stable Patch Classification



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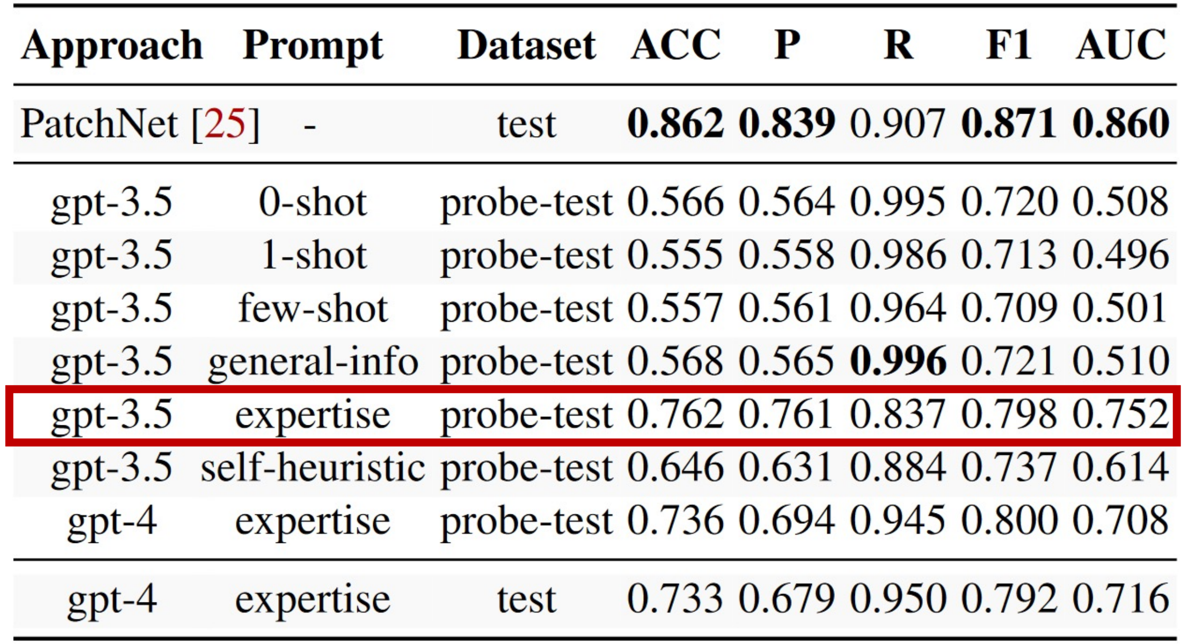
- ChatGPT performs slightly worse than the SOTA.
- In this task, gpt-4 and gpt-3.5 each have their advantages.
- **When using the 0-shot and 1-shot prompts, ChatGPT tends to report all patches as stable ones.**

  ChatGPT does not understand what a stable patch is. It tends to report all patches as stable ones. Thus, the precision scores are close to 0.5 while recall scores are close to 1.

Stable Patch Classification



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- ChatGPT performs slightly worse than the SOTA.
- In this task, gpt-4 and gpt-3.5 each have their advantages.
- When using the 0-shot and 1-shot prompts, ChatGPT tends to report all patches as stable ones.
- **Providing the definition of stable patch significantly improves ChatGPT's performance.**

"fixing a problem that causes a build error, an oops, a hang, data corruption, a real security issue, or some 'oh, that's not good' issue"

Summary

- We conduct the first large-scale evaluation to explore the capabilities of ChatGPT on vulnerability management.
- We compare ChatGPT with 11 SOTA approaches on 6 vulnerability management tasks by using a large-scale dataset containing 19,355,711 tokens.
- Our findings demonstrate that ChatGPT has excellent capabilities when processing several vulnerability management tasks.
- We also reveal the difficulties ChatGPT encountered and shed light on future research to explore better ways to leverage ChatGPT in vulnerability management tasks.

Thanks!

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