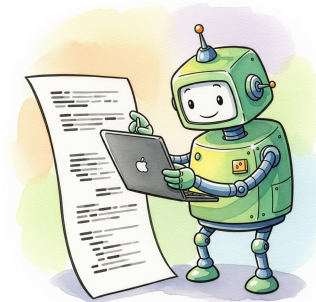




PatchAgent: A Practical Program Repair Agent Mimicking Human Expertise

Zheng Yu, Ziyi Guo, Yuhang Wu, Jiahao Yu, Meng Xu, Dongliang Mu, Yan Chen, Xinyu Xing

Northwestern University. University of Waterloo. Independent Researcher.





Agenda

- Motivation Example
- PatchAgent Design
- Evaluation and Results



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- PatchAgent Design
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A Global Buffer Overflow Bug

```
1  const M3OpInfo c_operations[] = { /* ... */ };
2  const M3OpInfo c_operationsFC[] = { /* ... */ };
3
4  static inline const M3OpInfo*
5  GetOpInfo(m3opcode_t opcode) {
6      switch (opcode >> 8) {
7          case 0x00:
8              return &c_operations[opcode];
9          case 0xFC:
10             return &c_operationsFC[opcode & 0xFF];
11         default:
12             return NULL;
13     }
14 }
15
16 M3Result
17 Compile_BlockStat(IM3Compilation o) {
18     m3opcode_t opcode;
19     Read_opcode (&opcode, &o);
20     IM3OpInfo opinfo = GetOpInfo(opcode);
21     _throwif(unknownOpcode, opinfo == NULL);
22     if (opinfo->compiler) { // global overflow
23         (*opinfo->compiler) (o, opcode)
24     } else {
25         Compile_Operator (o, opcode);
26     }
27 }
```

==35==ERROR: AddressSanitizer: global-buffer-overflow

READ of size 8 at 0x55bc18 thread T0

#0 0x55969b in [Compile_BlockStat](#) /source/m3_compile.c:22

#1 0x55c4c6 in [Compile_Block](#) /source/m3_compile.c:2277

#2 0x55cbc3 in [Compile_If](#) /source/m3_compile.c:1648

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#4 0x55ca29 in [Parse_InitExpr](#) /source/m3_parse.c:282

.....

#8 0x55d715 in [LLVMFuzzerTestOneInput](#) /app_fuzz/fuzzer.c:30

#9 0x552e14 in fuzzer::Fuzzer::ExecuteCallback (BuildId: f0fdeb36a)

.....

0x555bc18 is located 88 bytes after global variable **c_operations**

SUMMARY: AddressSanitizer: global-buffer-overflow

What ability do human/LLM have?



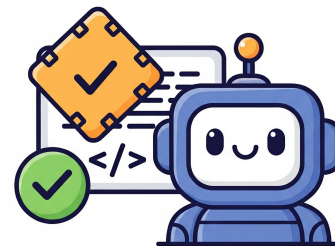
View Code

The viewcode API retrieves the code context by specifying file names and line numbers



Find Definition

The find_definition finds the definition location of symbols by specifying their names and reference locations



Validate

The validate API to check if the patch can mitigate the PoC and pass all functional tests



Human Expert

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Human Expert

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`opinfo` is an overflow pointer generated by GetOpInfo, I would like to locate its definition.





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The variable GetOpInfo is defined at line 5 in the /source/m3_compile.c.





Human Expert

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```
GetOpInfo(m3opcode_t opcode) {
    switch (opcode >> 8) {
    case 0x00:
        return &c_operations[opcode]; ....
```



Human Expert

```

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The report indicates that the overflow occurred in `c_operations`, so I need to add a boundary check before performing pointer arithmetic.



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IM3OpInfo opinfo = GetOpInfo(opcode);
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`'opinfo'` is an overflow pointer generated by `GetOpInfo`, I would like to locate its definition.



The variable `GetOpInfo` is defined at line 5 in the `/source/m3_compile.c`.



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0x55bc18 is located 88 bytes after global variable c_operations
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Final Patch

```
1 GetOpInfo(m3opcode_t opcode) {
2     switch (opcode >> 8) {
3         case 0x00:
4 +         if(opcode < sizeof(c_operations))
5             return &c_operations[opcode];
6 +         break;
7         case 0xFC:
8 +         if(opcode & 0xFF < sizeof(c_operations))
9             return &c_operationsFC[opcode & 0xFF];
10 +        break;
11        default:
12            return NULL;
13    }
14 }
```

According to the address sanitizer report, a global overflow occurred at line 22 in the `/source/m3_compile.c`. Let me view lines 17 to 27 in `/source/m3_compile.c`.



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Vanilla Agent

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```
m3opcode_t opcode;
read_opcode(&opcode,&o);
IM3OpInfo opinfo = GetOpInfo(opcode);
```

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```
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```

```
READ of size 8 at 0x55bc18 thread T0
```

```
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```

```
#1
```

```
#2
```

```
#3
```

```
#4
```

```
..
```

```
#8
```

```
#9
```

```
.....
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To address the global overflow vulnerability in the opinfo structure, you can introduce bounds checking before dereferencing. The patch ensure that opinfo points to a valid memory location



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IM3OpInfo opinfo = GetOpInfo(opcode);
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#1

#2

#3

#4

..

#8

#9

.....

0x555bc18 is located 88 bytes after global variable **c_operations**

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To address the global overflow vulnerability in the opinfo structure, you can introduce bounds checking before dereferencing. The patch ensure that opinfo points to a valid memory location



Final Patch

```
1 M3Result Compile_BlockStat(IM3Compilation o) {
2     m3opcode_t opcode;
3     Read_opcode (&opcode, &o);
4 +   if (opcode < 0 || opcode > MAX_OPCODE)
5 +       return unknownOpcode;
6     IM3OpInfo opinfo = GetOpInfo(opcode);
7     _throwif(unknownOpcode, opinfo == NULL);
8     if (opinfo->compiler) {
```



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IM3OpInfo opinfo = GetOpInfo(opcode);
```



Vanilla Agent

Too small code range

==35==ERROR: AddressSanitizer: global-buffer-overflow

READ of size 8 at 0x55bc18 thread T0

#0 0x55969b in **Compile_BlockStat** /source/m3_compile.c:22

#1

#2

#3

#4

..

#8

#9

.....

0x555bc18 is located 88 bytes after global variable **c_operations**

SUMMARY: AddressSanitizer: global-buffer-overflow



To address the global overflow vulnerability in the opinfo structure, you can introduce bounds checking before dereferencing. The patch ensure that opinfo points to a valid memory location

7

b36a)



Final Patch

```
1 M3Result Compile_BlockStat(IM3Compilation o) {
2     m3opcode_t opcode;
3     Read_opcode (&opcode, &o);
4 +   if (opcode < 0 || opcode > MAX_OPCODE)
5 +       return unknownOpcode;
6     IM3OpInfo opinfo = GetOpInfo(opcode);
7     _throwif(unknownOpcode, opinfo == NULL);
8     if (opinfo->compiler) {
```



According to the address sanitizer report, a global overflow occurred at line 22 in the /source/m3_compile.c. So I want to view lines 21 to 23 in /source/m3_compile.c.



```
_throwif(unknownOpcode, opinfo == NULL);
if (opinfo->compiler) {
    (*opinfo->compiler) (o, opcode)
```



It appears that the overflow occurs in opinfo. I would like to locate the definition of opinfo.



The variable opinfo is defined at line 20 in the /source/m3_compile.c.



Great, now I want to view lines 17 to 20 in /source/m3_compile.c



```
m3opcode_t opcode;
read_opcode(&opcode,&o);
IM3OpInfo opinfo = GetOpInfo(opcode);
```




Vanilla Agent

Too small code range

==35==ERROR: AddressSanitizer: global-buffer-overflow

READ of size 8 at 0x55bc18 thread T0

#0 0x55969b in Compile_BlockStat /source/m3_compile.c:22

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#8

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To address the global overflow vulnerability in the opinfo structure, you can introduce bounds checking before dereferencing. The patch ensure that opinfo points to a valid memory location

0x555bc18 is located 88 bytes after global variable **c_operations**

SUMMARY: AddressSanitizer: global-buffer-overflow



Final Patch

```
1 M3Result Compile_BlockStat(IM3Compilation o) {
2     m3opcode_t opcode;
3     Read_opcode (&opcode, &o);
4 +   if (opcode < 0 || opcode > MAX_OPCODE)
5 +       return unknownOpcode;
6     IM3OpInfo opinfo = GetOpInfo(opcode);
7     _throwif(unknownOpcode, opinfo == NULL);
8     if (opinfo->compiler) {
```

Why not continue exploring related function?



According to the address sanitizer report, a global overflow occurred at line 22 in the /source/m3_compile.c. So I want to view lines 21 to 23 in /source/m3_compile.c.



```
_throwif(unknownOpcode, opinfo == NULL);
if (opinfo->compiler) {
    (*opinfo->compiler) (o, opcode)
```



It appears that the overflow occurs in opinfo. I would like to locate the definition of opinfo.



The variable opinfo is defined at line 20 in the /source/m3_compile.c.



Great, now I want to view lines 17 to 20 in /source/m3_compile.c



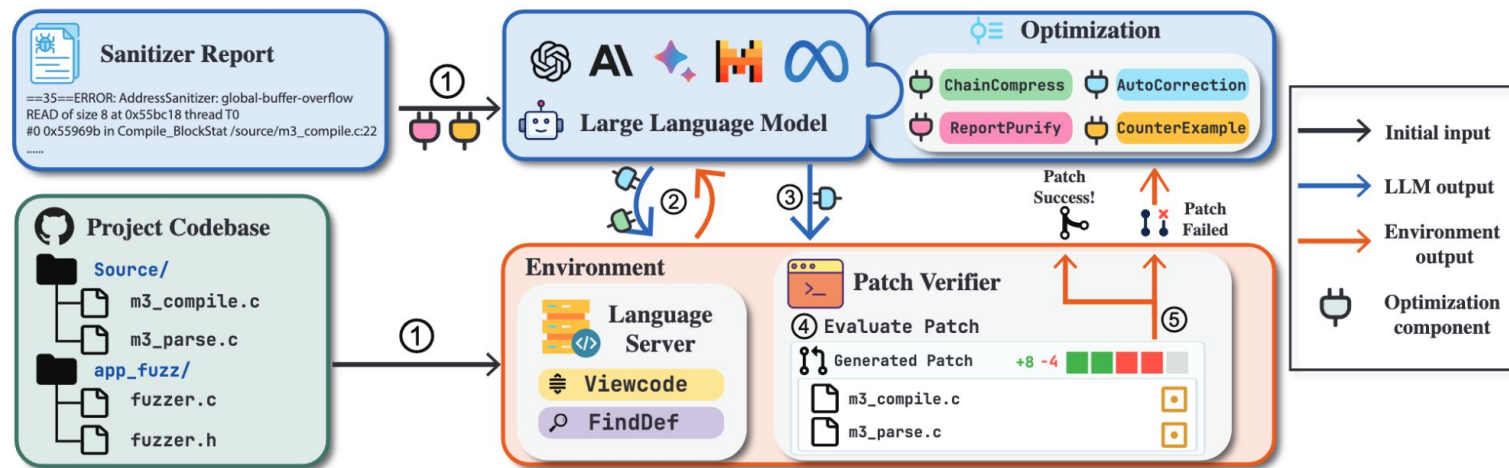
```
m3opcode_t opcode;
read_opcode(&opcode, &o);
IM3OpInfo opinfo = GetOpInfo(opcode);
```



Agenda

- Motivation Example
- PatchAgent Design
- Evaluation and Results

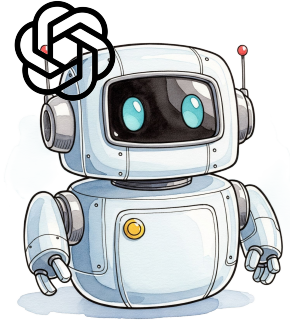
Patch Agent



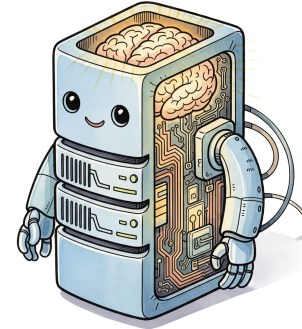
The process begins with the **sanitizer report** and the **project codebase** (1). The LLM retrieves the code context using the **viewcode** and **find_definition** APIs (2) and then **generates a patch** (3). The patch is subsequently validated by the patch verifier (4). If the patch is incorrect, the agent will **refine the patch or gather additional context** (5), iterating until a correct patch is generated or the budget is exhausted.

Auto Correction

Common Tool Call Process



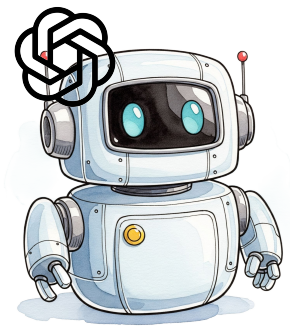
LLM



Environment
(Language Server)

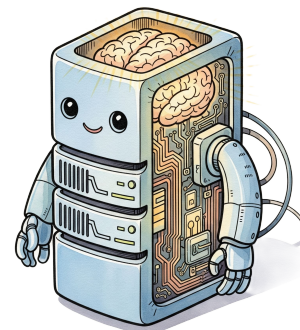
Auto Correction

Common Tool Call Process



LLM

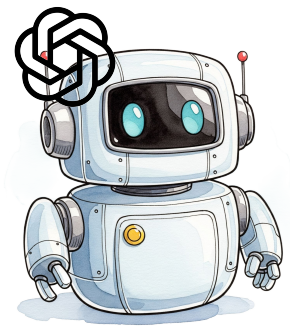
```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 21,  
  "end_line": 23  
}
```



Environment
(Language Server)

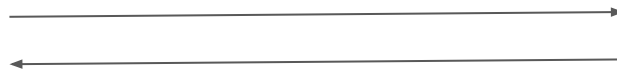
Auto Correction

Common Tool Call Process

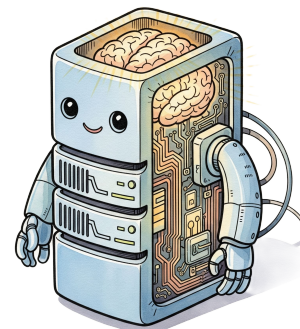


LLM

```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 21,  
  "end_line": 23  
}
```



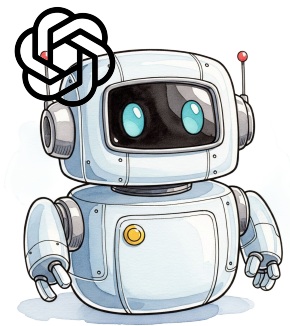
```
21| _throwif(unknownOpcode, opinfo = NULL);  
22| if (opinfo->compiler) {  
23|   (*opinfo->compiler) (o, opcode)
```



Environment
(Language Server)

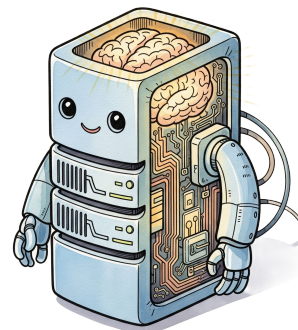
Auto Correction

Tool Call Process (with Auto Correction)



LLM

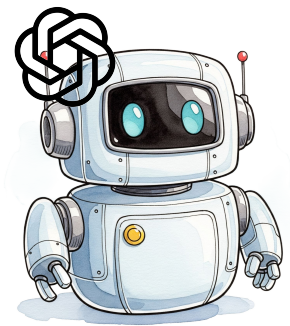
```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 21,  
  "end_line": 23  
}
```



Environment
(Language Server)

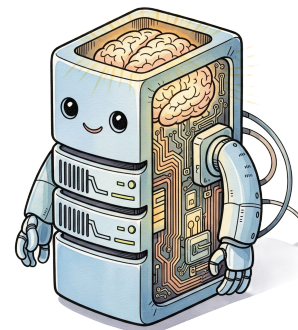
Auto Correction

Tool Call Process (with Auto Correction)



LLM

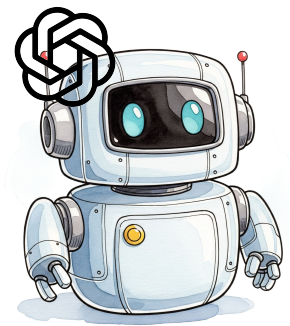
```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 21,  
  "end_line": 23  
}
```



Environment
(Language Server)

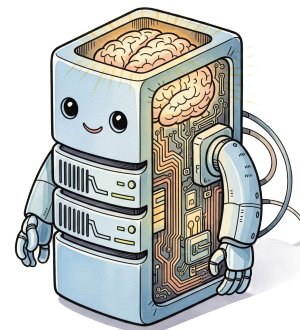
Auto Correction

Tool Call Process (with Auto Correction)



LLM

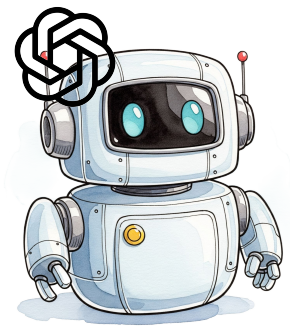
```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 17,  
  "end_line": 27  
}
```



Environment
(Language Server)

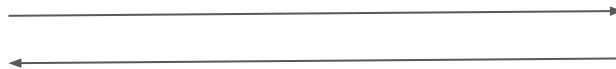
Auto Correction

Tool Call Process (with Auto Correction)

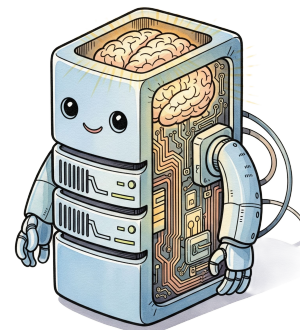


LLM

```
{  
  "action": "viewcode",  
  "path": "src/m3_compile.c",  
  "start_line": 17,  
  "end_line": 27  
}
```



```
17| Compile_BlockStat(IM3Compilation o) {  
18|   m3opcode_t opcode;  
19|   Read_opcode (&opcode, &o);  
20|   IM3OpInfo opinfo = GetOpInfo(opcode);  
21|   _throwif(unknownOpcode, opinfo == NULL);  
22|   if (opinfo->compiler) {  
23|     (*opinfo->compiler) (o, opcode)  
24|   } else {  
25|     Compile_Operator (o, opcode);  
26|   }  
27| }
```



Environment
(Language Server)



Auto Correction

Code Viewing Enhancement

Expanded code range visibility and corrected file path references

- Resolved issues with narrow code display windows that limited readability
- Fixed incorrect file path typos that were breaking navigation links

Symbol Definition Resolution

Enhanced alias symbol detection and lookup

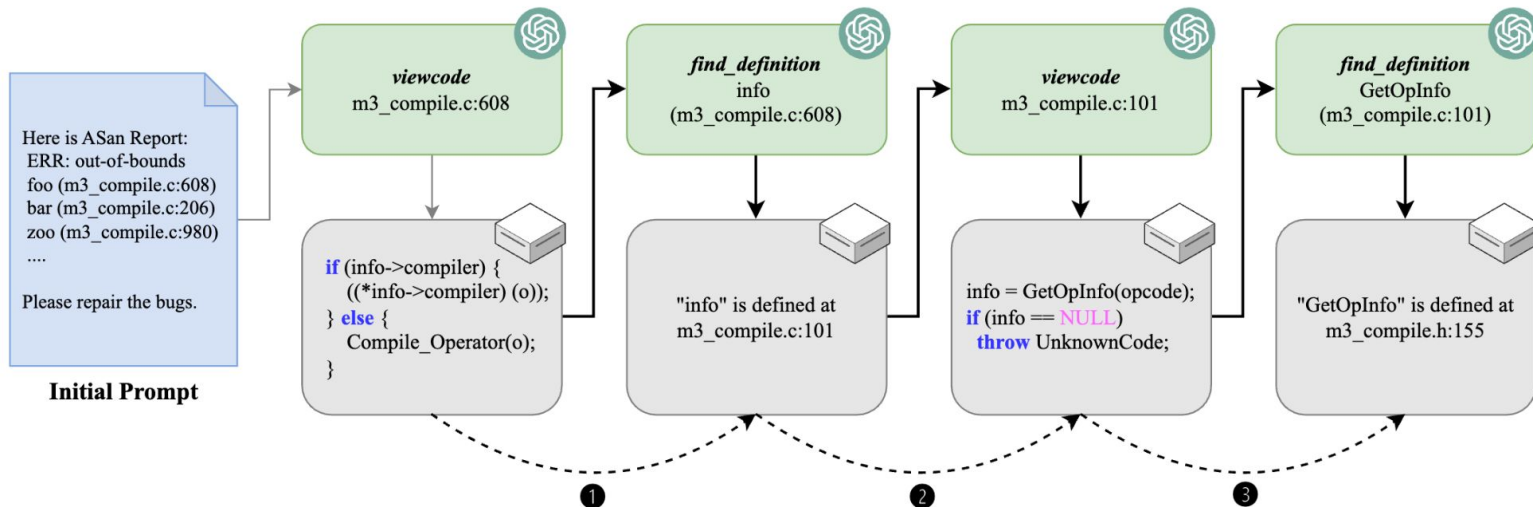
- Improved the "Find Definition" feature to properly handle aliased symbols
- Resolved cases where symbol aliases were not being recognized or linked correctly

Validation System Updates

Standardized patch format processing

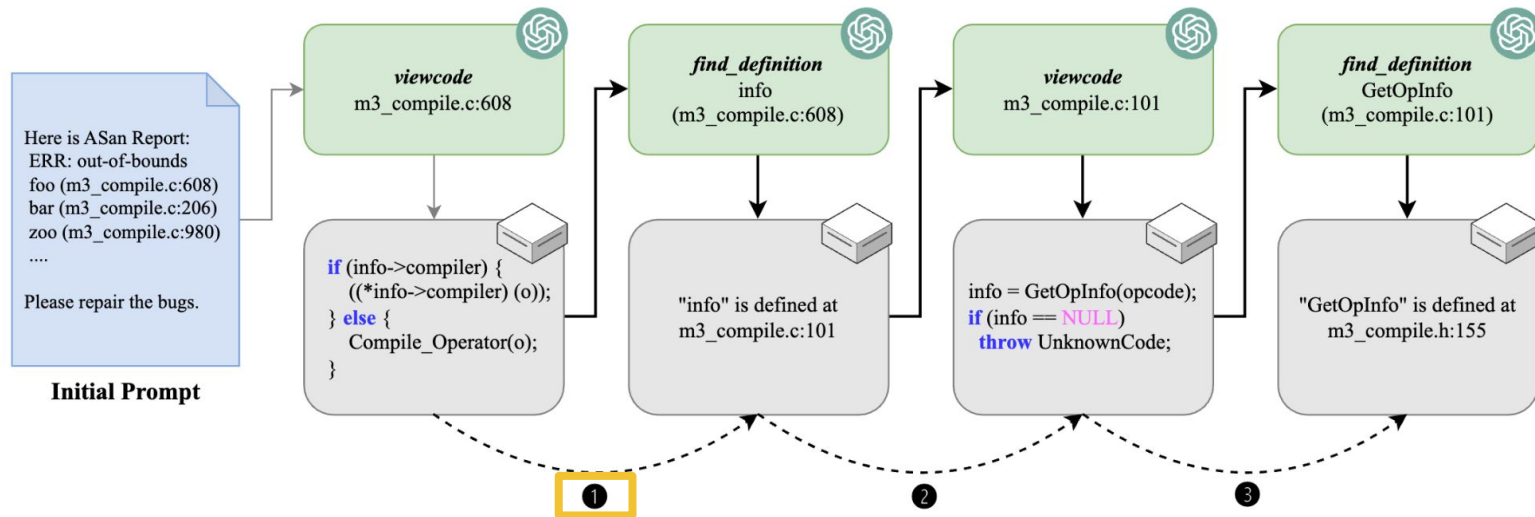
- Fixed validation errors related to inconsistent patch formats
- Ensured all patch submissions now follow proper formatting standards

Chain Compression



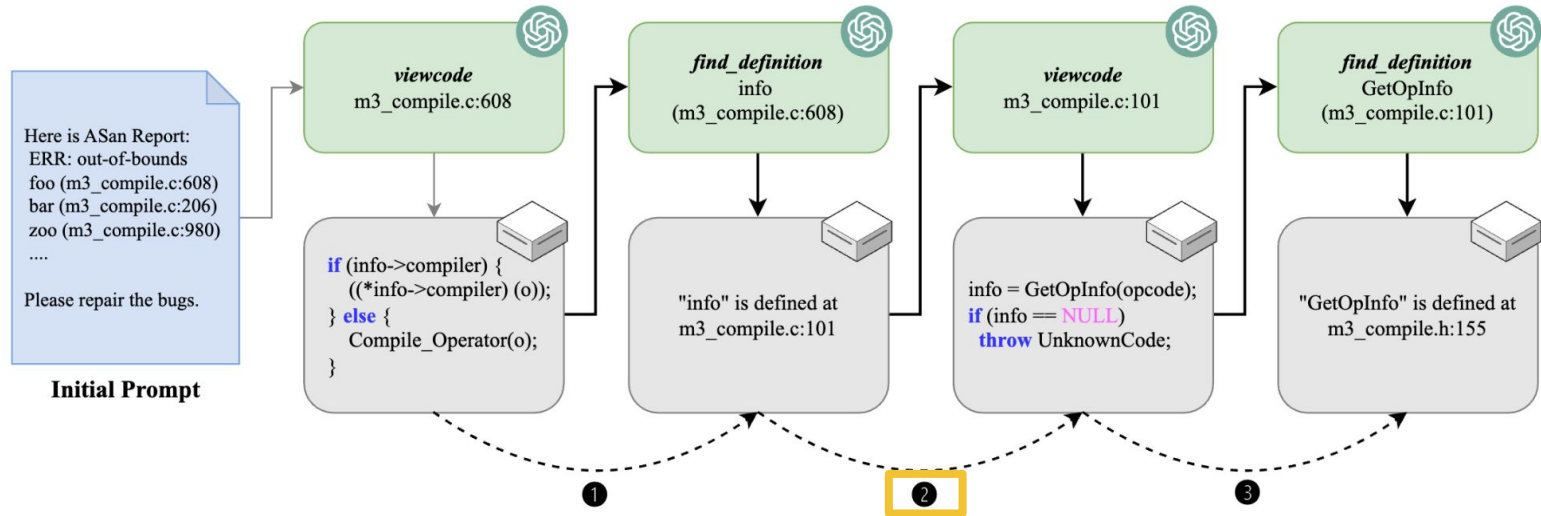
The LLM takes the initial prompt as input and starts interacting with the language server. The black bold arrows illustrate the interaction without chain compression, while the black dashed arrows represent the **compressed interaction process**. The original interaction **chain of length four** was compressed into a **single interaction**.

Chain Compression



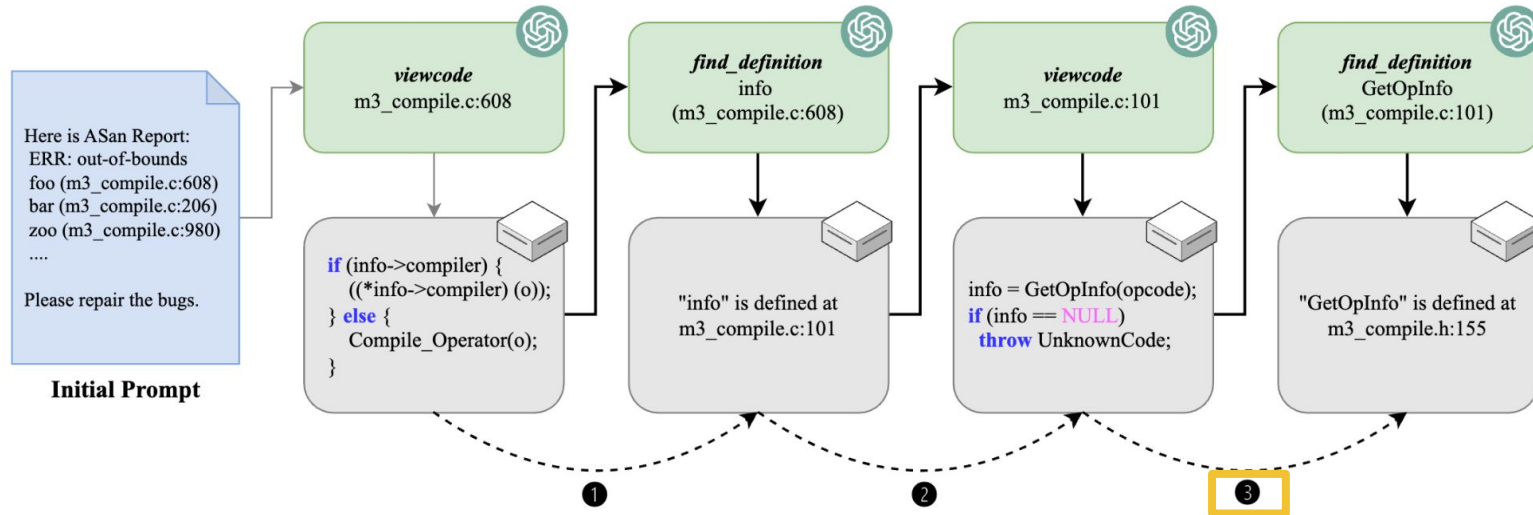
1. After the LLM sends a viewcode action, the mechanism determines that the crash is caused by the dereference of `info` and the line where `info` located **appears in both the viewed code snippet and the sanitizer report**. This indicates that it is a valuable symbol to explore.

Chain Compression



2. Using only the find_definition action to locate the definition of info is **insufficient to reveal its complete information**. Therefore, the mechanism first generates another viewcode action to obtain the definition code snippet of info.

Chain Compression



3. Then, it identifies that the variable relies on another symbol, GetOpInfo, and recursively finds its definition location.



Agenda

- Motivation Example
- PatchAgent Design
- Evaluation and Results



Dataset Overview

We created a dataset comprising 178 cases sourced from OSS-Fuzz , Huntr and ExtractFix on **9 distinct bug types**: stack overflow, heap overflow, integer overflow, use-after-free, double free, global overflow, divide by zero, invalid free, and null dereference.

| Project | Lang | Source | LoC | #Vulns | #Test |
|------------|------|------------|--------|--------|-------|
| assimp | C++ | OSS-Fuzz | 347.0K | 3 | 474 |
| c-blosc | C | OSS-Fuzz | 88.8K | 2 | 1643 |
| c-blosc2 | C++ | OSS-Fuzz | 117.1K | 7 | 1284 |
| h3 | C | OSS-Fuzz | 17.2K | 1 | 124 |
| hoextdown | C | OSS-Fuzz | 7.1K | 1 | 83 |
| hostap | C | OSS-Fuzz | 438.0K | 4 | 19 |
| htslib | C | OSS-Fuzz | 66.5K | 1 | 159 |
| hunspell | C++ | OSS-Fuzz | 83.9K | 11 | 128 |
| irssi | C | OSS-Fuzz | 64.4K | 3 | 5 |
| krb5 | C | OSS-Fuzz | 301.6K | 1 | 125 |
| libplist | C | OSS-Fuzz | 12.1K | 3 | 34 |
| libsndfile | C | OSS-Fuzz | 56.4K | 5 | 141 |
| libtpms | C | OSS-Fuzz | 115.0K | 1 | 6 |
| libxml2 | C | OSS-Fuzz | 200.4K | 10 | 3272 |
| lz4 | C | OSS-Fuzz | 18.6K | 2 | 22 |
| md4c | C | OSS-Fuzz | 8.0K | 4 | 24 |
| openexr | C++ | OSS-Fuzz | 227.8K | 3 | 111 |
| sleuthkit | C | OSS-Fuzz | 196.2K | 5 | 2 |
| wasm3 | C | OSS-Fuzz | 22.8K | 8 | 35062 |
| zstd | C | OSS-Fuzz | 93.4K | 5 | 28 |
| gpac | C | Huntr | 743.7K | 32 | 711 |
| libmobi | C | Huntr | 19.1K | 5 | 12 |
| mruby | C | Huntr | 62.2K | 10 | 61 |
| radare2 | C | Huntr | 841.3K | 20 | 858 |
| yasm | C | Huntr | 132.1K | 3 | 44 |
| binutils | C | ExtractFix | 666.8K | 2 | 20 |
| coreutils | C | ExtractFix | 86.1K | 4 | 573 |
| jasper | C | ExtractFix | 44.7K | 2 | 16 |
| libjpeg | C | ExtractFix | 46.9K | 4 | 530 |
| libtiff | C | ExtractFix | 85.9K | 11 | 74 |
| libxml2 | C | ExtractFix | 200.4K | 5 | 3272 |



Effectiveness Evaluation

| Model | Temporal Error | Spatial Error | Null Dereference | Numeric Error | Total |
|-----------------|----------------|------------------|------------------|---------------|------------------|
| GPT-4o | 13/23 (56.52%) | 96/125 (76.80%) | 23/23 (100.00%) | 7/7 (100.00%) | 139/178 (78.09%) |
| GPT-4 Turbo | 11/23 (47.83%) | 87/125 (69.60%) | 21/23 (91.30%) | 7/7 (100.00%) | 126/178 (70.79%) |
| Claude-3 Opus | 14/23 (60.87%) | 108/125 (86.40%) | 22/23 (95.65%) | 7/7 (100.00%) | 151/178 (84.83%) |
| Claude-3 Sonnet | 8/23 (34.78%) | 77/125 (61.60%) | 17/23 (73.91%) | 6/7 (85.71%) | 108/178 (60.67%) |
| Claude-3 Haiku | 9/23 (39.13%) | 93/125 (74.40%) | 19/23 (82.61%) | 7/7 (100.00%) | 128/178 (71.91%) |
| Union | 20/23 (86.96%) | 114/125 (91.20%) | 23/23 (100.00%) | 7/7 (100.00%) | 164/178 (92.13%) |

This table compares the effectiveness of **PatchAgent** when utilizing different LLMs to repair vulnerabilities. The **Union** row represents the combined results of **PatchAgent** across all models, demonstrating the overall improvement in repair accuracy achieved through the collaborative use of multiple models.



Github Pull Requests

LIBSSH2
HDF5



LibreDWG



Fix vuln OSV-2024-947 #1699



seladb merged 8 commits into [seladb:dev](#) from [oss-patch:patch-OSV-2024-947](#) on Mar 29

Fix vuln OSV-2023-77 #5210



Irknnox merged 7 commits into [HDFGroup:develop](#) from [oss-patch:patch-OSV-2023-77](#) on Jan 15

Fix buffer overflow in MD3Loader #5763



kimkulling merged 2 commits into [assimp:master](#) from [cla7aye15I4nd:fix-5616](#) on Sep 10, 2024

kex: fix null pointer dereference in `diffie_hellman_sha_algo()` #1508



willco007 merged 1 commit into [libssh2:master](#) from [oss-patch:patch-crash-c7c664759c840b3f1c438b7232f713b756ed640f](#) on Feb 28

Fix Heap-buffer-overflow in `__parse_options` #1678



tigercosmos merged 5 commits into [seladb:dev](#) from [oss-patch:patch-crash-7d18f37e1f05e0ff4aa4dfa2f67dd738340ad9cf](#) on Feb 2

Fix vuln OSV-2024-390 #5201



Irknnox merged 1 commit into [HDFGroup:develop](#) from [oss-patch:patch-OSV-2024-390](#) on Jan 3

Fix vuln OSV-2024-384 #1061



rurban merged 1 commit into [LibreDWG:master](#) from [oss-patch:patch-OSV-2024-384](#) on Dec 24, 2024

Fix vuln OSV-2024-343 #1680



seladb merged 2 commits into [seladb:dev](#) from [oss-patch:patch-OSV-2024-343](#) on Jan 11



pcapPlusPlus



Thanks



Home Page



Github (star it!)