CARIAD

Master Thesis: AI Usage in CI/CD/CT Pipelines for Compute Platforms in Automotives

We transform automotive mobility

CARIAD
A VOLKSWAGEN GROUP COMPANY

Agenda

// Introduction

// Method

// Result

/7 Status

// Next Steps

Introduction

Introduction

- Rapidly growing software complexity & shorter release cycles
- Automotive ECUs are safety-critical, hence zero tolerance
- Traditional security tests cannot keep pace with CI/CD demand

Problem Statement

- Current white-box fuzzing & testing are manual or slow to scale
- Vulnerabilities may slip through nightly CI due to time limits
- Need an AI-guided approach integrated into CI/CD/CT to
  – boost path coverage
  – reduce manual fuzz test case creation
  – auto-generate actionable test artifacts

Research Objectives

Technique Design

- AI-assisted white-box fuzzing for automotive targets

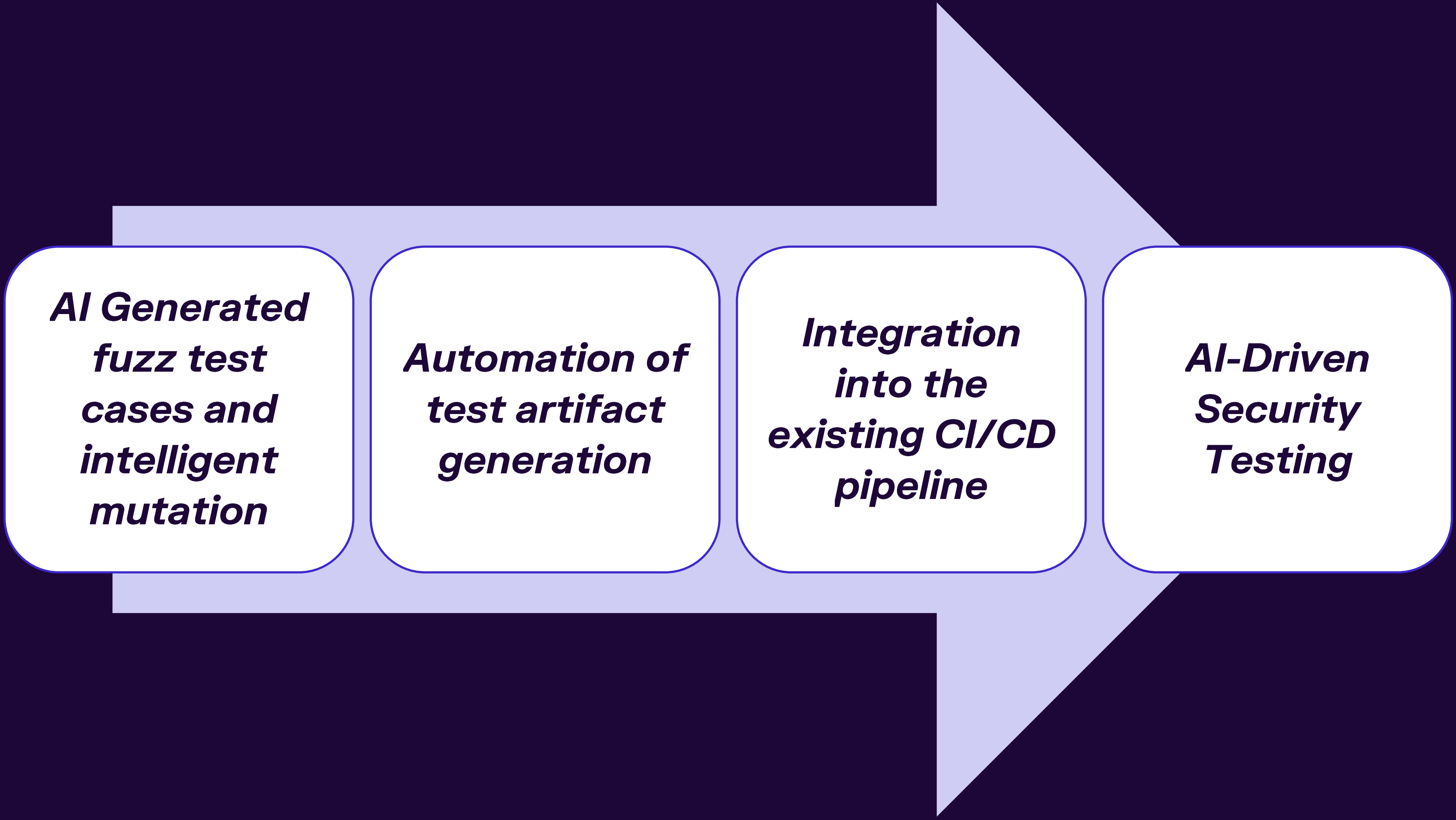
Pipeline Integration

- Embed continuous fuzzing into existing CI/CD/CT

Artifact & Impact Automation

- Auto-generate test cases, reports, quality matrix
- Measure coverage, MTTV, and CI latency vs. baseline

Expected Outcomes



AI Generated fuzz test cases and intelligent mutation

Automation of test artifact generation

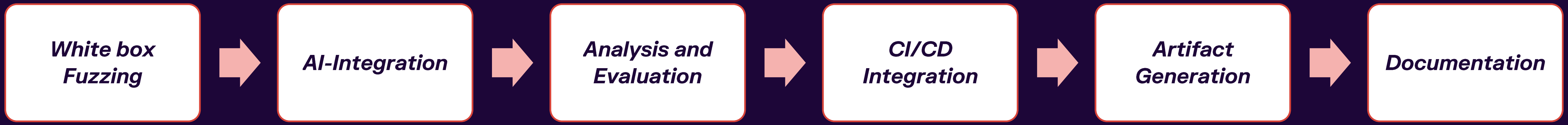
Integration into the existing CI/CD pipeline

AI-Driven Security Testing

May

Method

Overview



White box Fuzzing

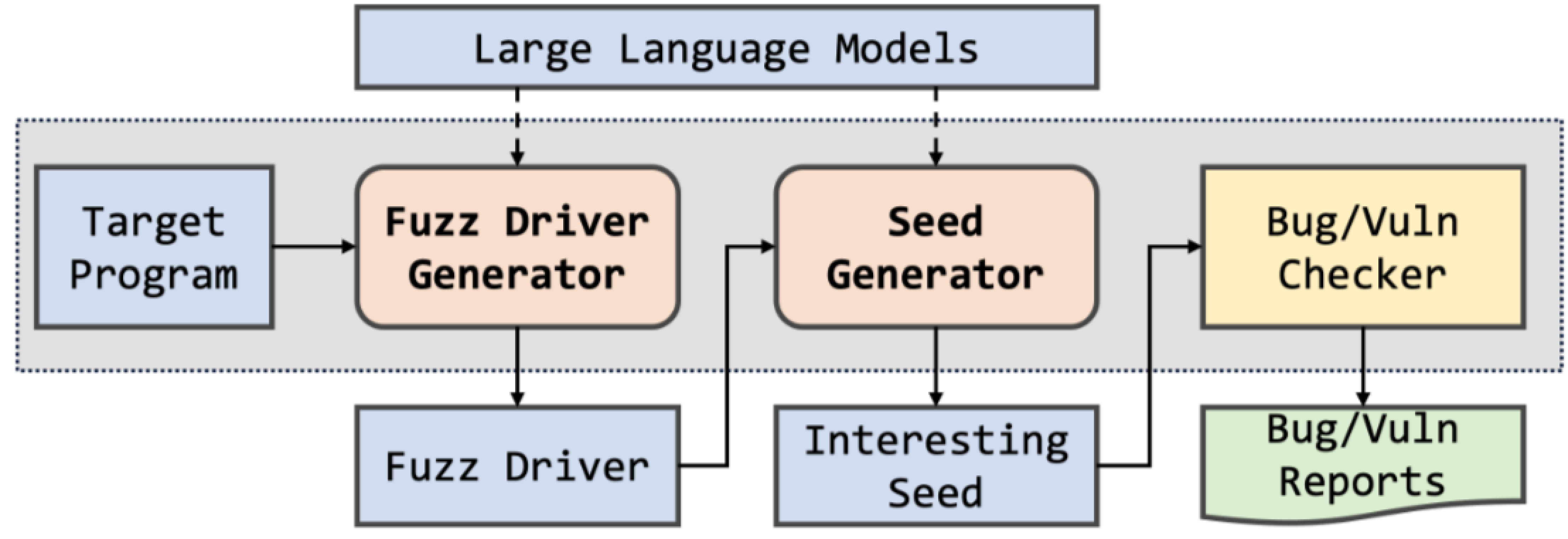
AI-Integration

Analysis and Evaluation

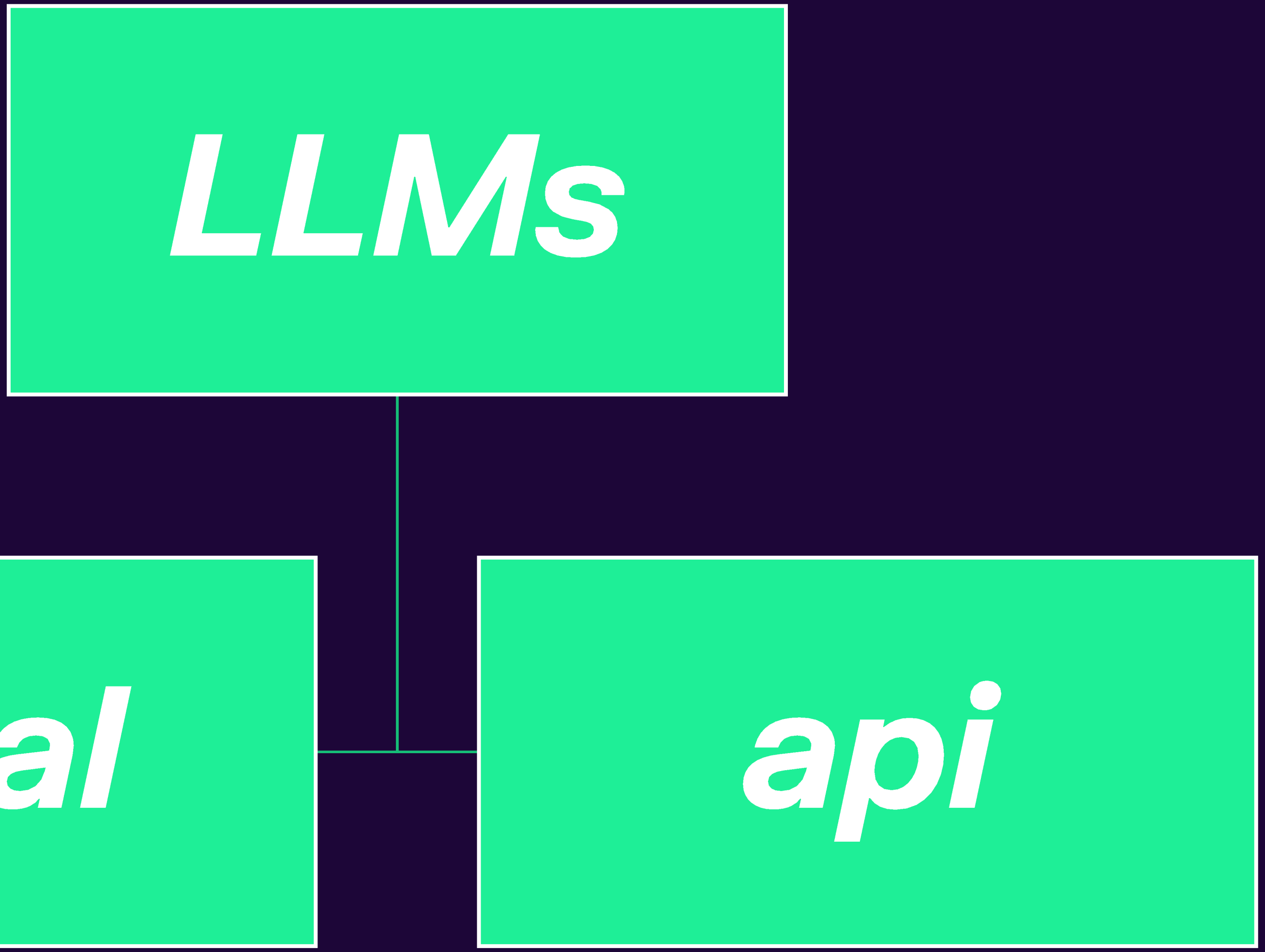
CI/CD Integration

Artifact Generation

Documentation


Large Language Models
Target Program
Fuzz Driver Generator
Seed Generator
Bug/Vuln Checker
Fuzz Driver
Interesting Seed
Bug/Vuln Reports

Method

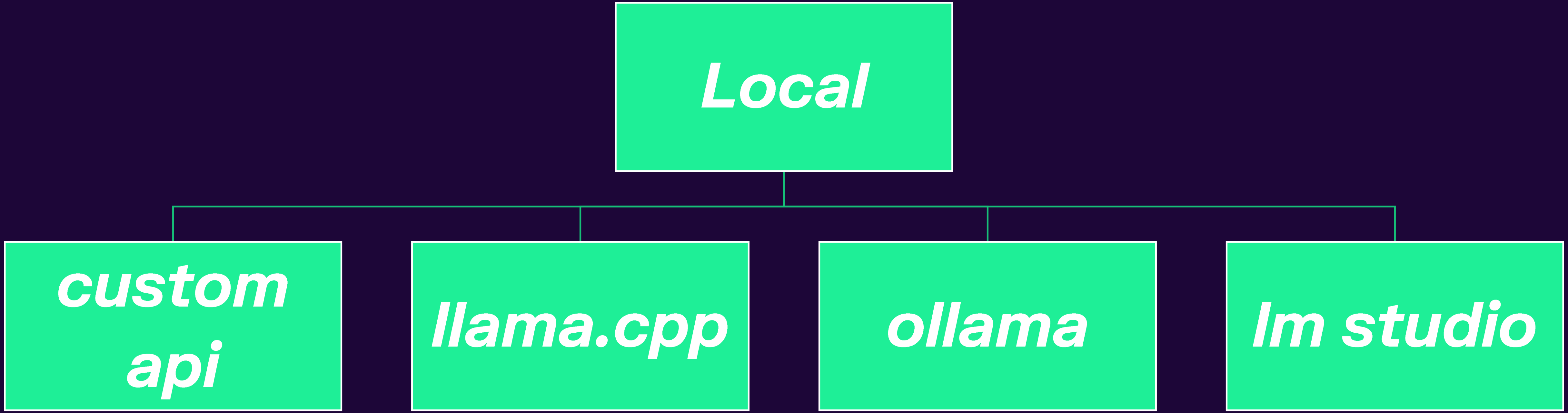


LLMs

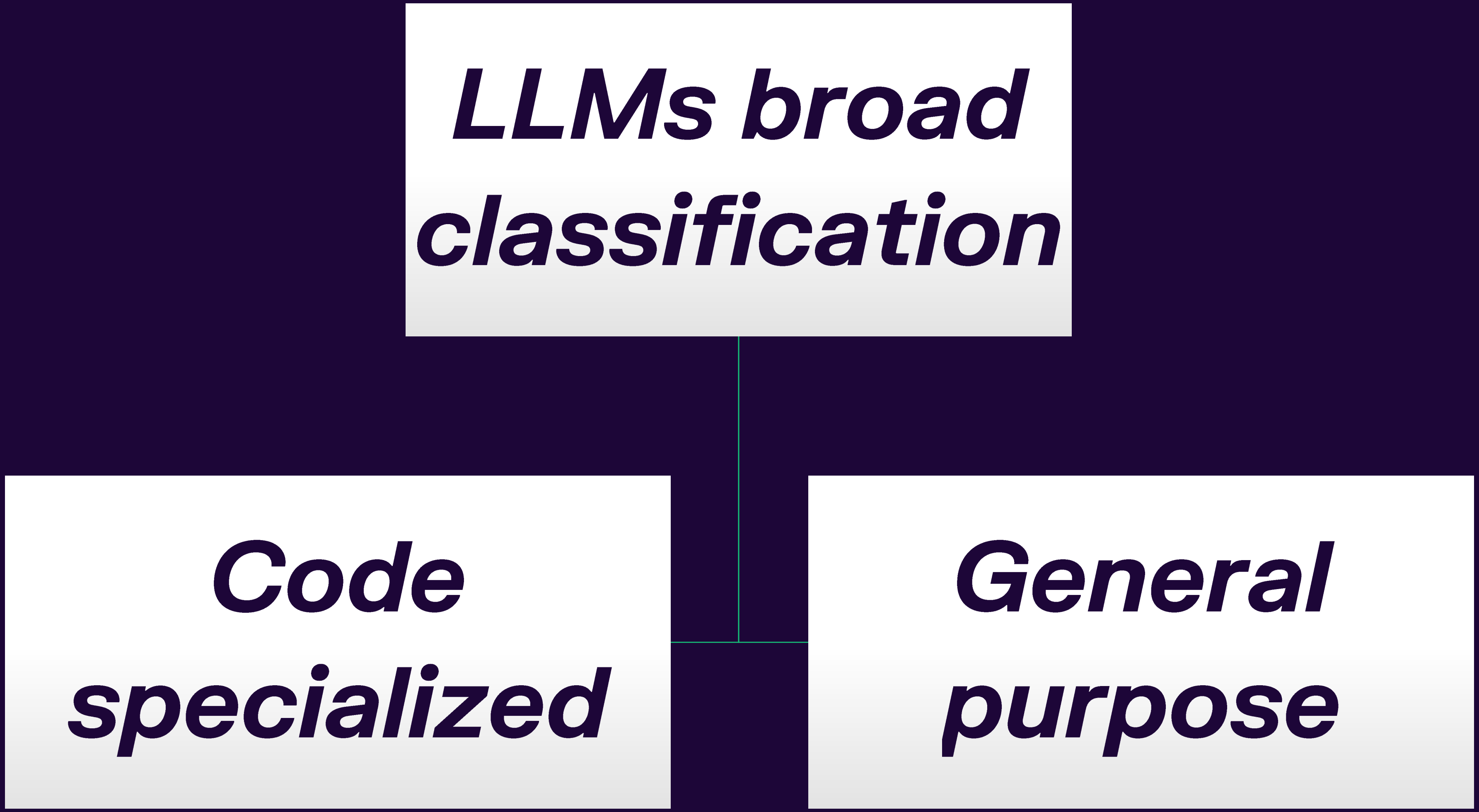
local

api

Method



Method

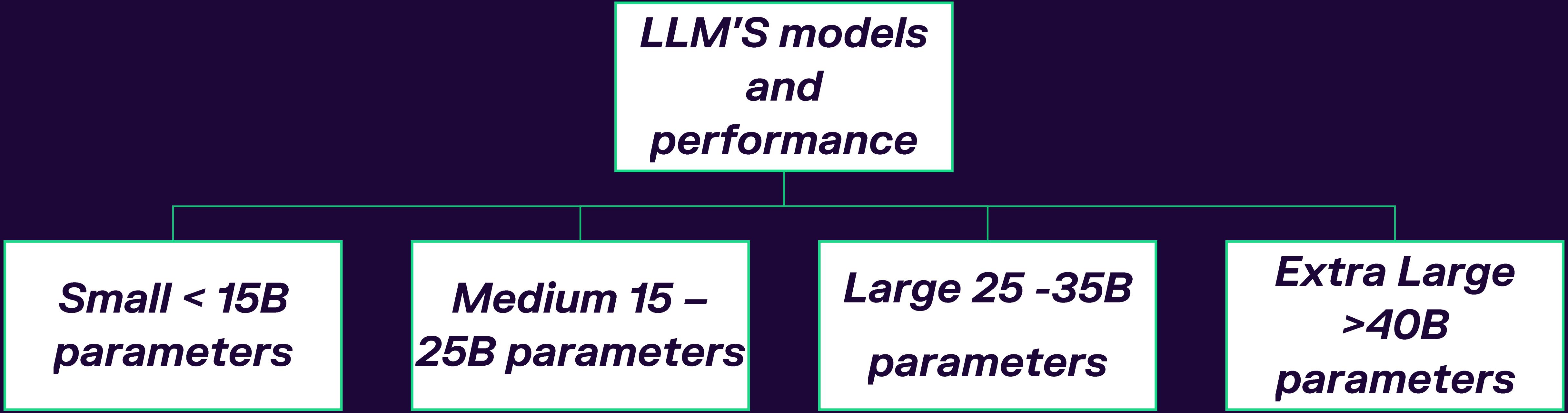


LLMs broad classification

Code specialized

General purpose

Method



LLM'S models and performance

Small < 15B parameters

Medium 15 – 25B parameters

Large 25 -35B parameters

Extra Large >40B parameters

Models

Large (25-35B parameters)

- gemma3:27b (27.4B)
- qwen3:32b (32.8B)
- deepseek-r1:32b (32.8B)
- qwen2.5-coder:32b (32.8B)
- deepseek-coder:33b (33B)
- wizardcoder:33b (33B)
- codellama:34b-instruct (34B)
- yi:34b (34B)

Models

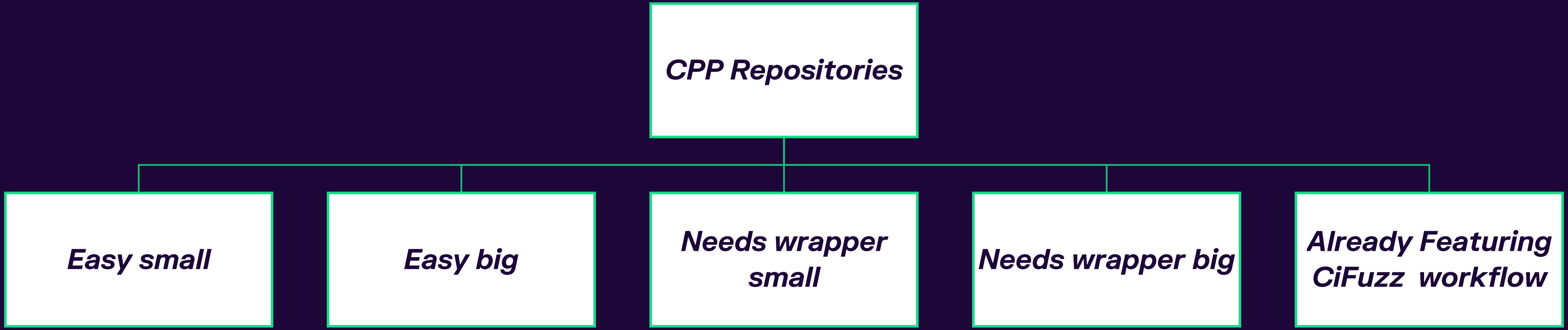
Extra Large (> 40B parameters)

- mixtral:latest (46.7B)

Previously Iterations

- qwen2.5-coder:7b (7B)
- qwen2.5-coder:14b (14B)
- qwen1.5:7b (7B)

Repositories



CPP Repositories

Easy small

Easy big

Needs wrapper small

Needs wrapper big

Already Featuring CiFuzz workflow

repositories

Evaluation Framework

Metrics:

- *Number of bugs found*
- *Code coverage percentage*
- *Time to generate fuzz tests*
- *Quality of generated code (measured via static analysis or manual review)*
- *Number of tokens used*

Finetuning local llms

Qwen 2.5 coder 32b instruct full model 60gb

LoRA (Low-Rank Adaptation)

- LoRA rank (r): 16 – controls adaptation size
- LoRA alpha: 32 – scaling for adaptation
- Dropout: 0.1 – prevents overfitting
- Target modules: q_proj, v_proj, etc. – efficient fine-tuning
- Device: auto – runs on best available hardware
- Dtype: float16 – faster, less memory
- Efficient model loading and saving (safetensors)

Code examples for training

Jsonl format

{"prompt": "Generate a comprehensive parser fuzzer for structured data\n\nRequirements:\n- Maximize code coverage and edge case detection\n- Generate intelligent, targeted inputs\n- Optimize for vulnerability discovery speed\n- Include comprehensive error handling„

Code examples for training

Qwen 2.5 coder 32b

```
"completion":
"void train_timing_attack(const uint8_t* data, size_t size) {\n    if (size < 20) return;\n    \n    const
char* secret = \"supersecretpassword123\";\n    std::string user_input(reinterpret_cast<const
char*>(data), \n                          std::min(size, strlen(secret)));\n    \n    auto start =
std::chrono::high_resolution_clock::now();\n    \n    // VULNERABLE: Early return creates timing
difference\n    bool matches = true;\n    for (size_t i = 0; i < strlen(secret) && i < user_input.length();
i++) {\n        if (secret[i] != user_input[i]) {\n            matches = false;\n            break;  // Early return
reveals timing information\n        }\n        // Simulate processing time\n    }\n    \n    auto end =
std::chrono::high_resolution_clock::now();\n    auto duration =
std::chrono::duration_cast<std::chrono::microseconds>(end - start);\n    \n    printf(\"Password
check took %ld microseconds, match: %s\\n\", \n           duration.count(), matches ? \"true\" :
\"false\");\n}"}
```

Finetuning

- 32b – needs more than 60gb ram
- 14b – (32 – 37gb) ram
- 7b – 24gb ram without any background process
- 1.5b – 14gb ram

Finetuning

NAME	SIZE
qwen2.5-coder:1.5b	986 MB
qwen-fuzzer-1.5-709-examples:latest	3.1 GB
qwen-fuzzer-1.5-172-examples:latest	3.1 GB

Finetuning - Successful llms

Yaml cpp (35 files, 1061 candidates)

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Qwen 2.5 coder 1.5b	same	15 m	112k		
172 examples	same	12 m	65k		
709 examples	same	10 m	50k		

Result

Models - Successful llms

Code intelligence advanced setup

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Phi 14b	100%	12m 8s	59.8k	0	0
Llama 3	100%	3m 41s	27.6k	0	0
Qwen 1.5 7b	89.47%	6m 9s	50k	0	0

Models - Successful llms

Yaml cpp (35 files, 1061 candidates)

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Qwen 2.5 coder 32b	43.08%	32m 57s	45.1k	2.04k	2
Gemma 3 27b	45.06%	33m 33s	40.2k	2.05k	2
Phi 14b	34.26%	36m 36s	71.5k	2.22k	1

Models - Unsuccessful llms

Yaml cpp (35 files, 1061 candidates)

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Codellama 32b	0.00%	50m 43s	74k	0	0
Deepseek r1	0.00%	1h 36m 53s	54.9k	0	0
Deepseek code	0.00%	1h 37m 39s	48.8k	0	0
devstral	0.00%	38m 57s	82.6k	0	0
Llama 3 7b	0.00%	27m 40s	268k	0	0
Starcoder 2 15	0.00%	19m 55s	114k	0	0
Wizardcoder	0.00%	32m 15s	32.5k	0	0
Yi 34b	0.00%	2h 39m 53s	74.9k	0	0
Magistral 24b	0.00%	-	-	0	0
Mixtral	0.00%	-	-	0	0

Models - UnSuccessful llms

fmt

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Qwen 2.5 coder 32b	0.00%	43m 20s	59.8k	0	0
Gemma 3 27b	0.00%	41m 59s	73.9k	0	0

Models - Successful llms

pugixml

Models	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
Qwen 2.5 coder 32b	34.77%	37m 24s	43.1k	2.5k	1
Gemma 3 27b	0.00%	1h 12m 8s	122k	0	0

Models - Successful llms

Qwen 2.5 coder 32b

Repositories	Code Coverage	Time Taken	No of tokens used	Unique test cases	Successfull fuzz tests
jsoncons	45.64%	37m 24s	43.1k	2.5k	1
glm	0.00%	42m 55s	56.8k	0	0
spdlog	0.00%	49m 33s	62.9k	0	0

Final Steps

Next steps

Evaluation

Comparison of different local llms

Comparison between local and cloud llms

This thesis focuses on integrating AI and LLMs into CI/CD/CT pipelines to improve the security testing of automotive software

Thank you!

Any Questions