LineVul: A Transformer-based Line-Level Vulnerability Prediction

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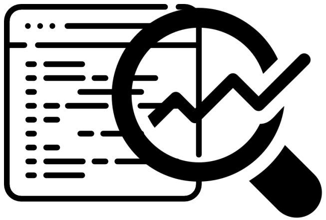
Challenges in Vulnerability Detection Practices

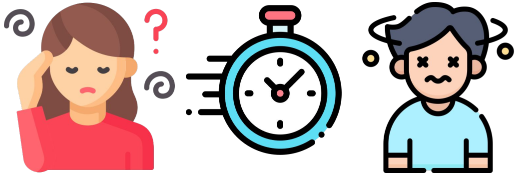
Software Vulnerabilities are costly and prevalent

But hard to detect and prevent



Static Analysis Tools have been proposed

But they are still inaccurate



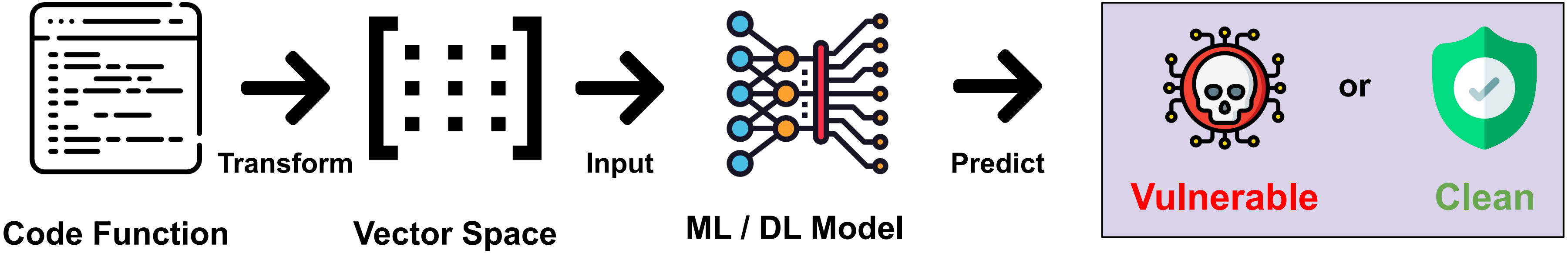
Within an project consists of millions lines of code

Security analysts may spend a huge amount of time

in order to locate the exact vulnerabilities

Vulnerability Prediction Model: An Overview

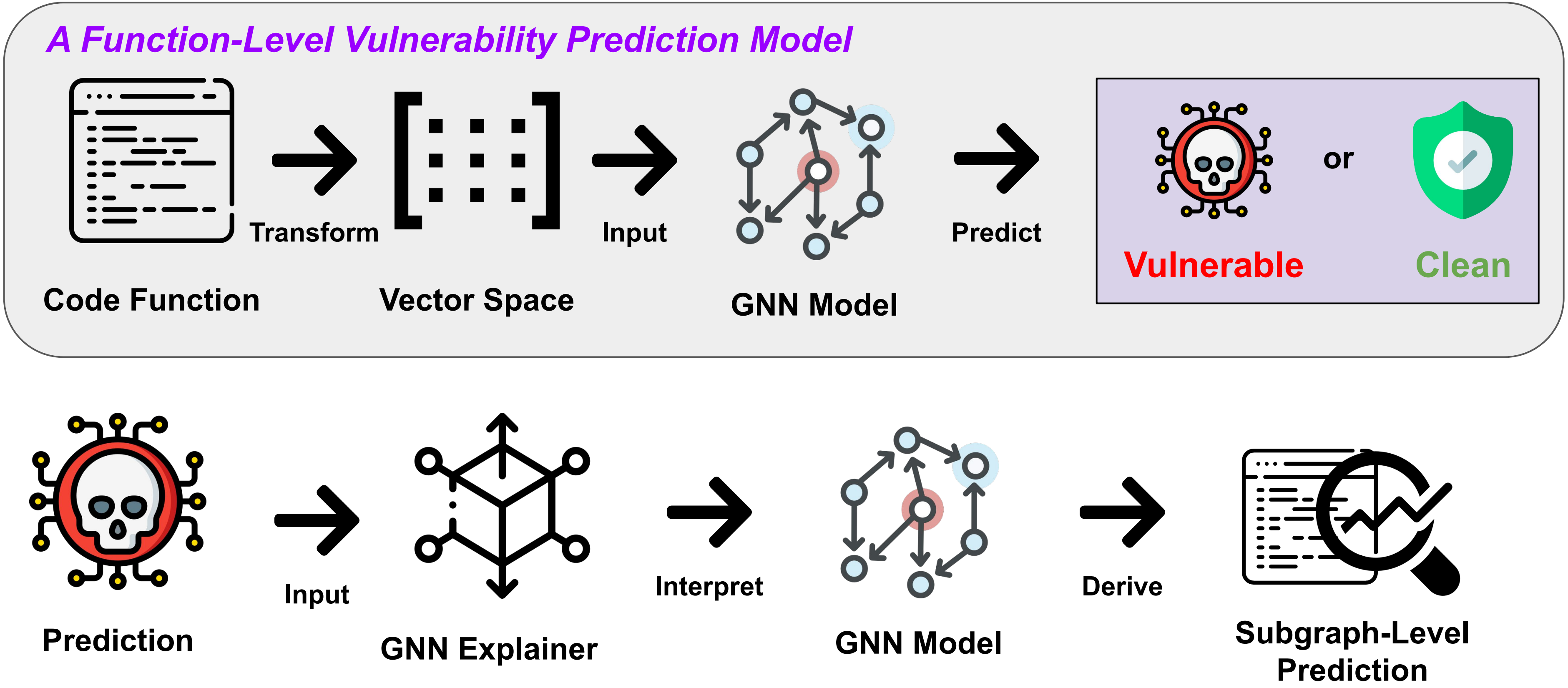
A model to predict if a function is a vulnerable function or not



Now Security Analysts are able to locate which function is a potential vulnerable function

However, a vulnerable function may still contain many lines of code for Security Analysts to inspect

IVDetect: A Fine-Grained Vulnerability Prediction Approach

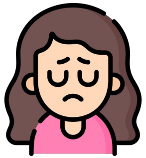


Now Security Analysts are able to locate which part of a function is a potential vulnerable function

Example Subgraph-Level Prediction of IVDetect

An example prediction of IVDetect using real world data

// Subgraph-Level Vulnerability Predictions by IVDetect			
third_party/WebKit/Source/core/frame/ImageBitmap.cpp https://github.com/chromium/chromium/commit/d59a4441697f6253e7dc3f7ae5caad6e5fd2c778		IVDetect	Ground truth
224	static sk_sp<SkImage> unPremulSkImageToPremul (SkImage* input) {	0	0
225	SkImageInfo info = SkImageInfo::Make(input->width(), input->height(),	0	0
226	kN32_SkColorType, kPremul_SkAlphaType);	0	0
227	RefPtr<Uint8Array> dstPixels = copySkImageData(input, info);	0	0
228	if (!dstPixels)	1	0
229	return nullptr;	0	0
230	return newSkImageFromRaster(	1	0
231	info, std::move(dstPixels),	1	0
232	static_cast<size_t>(input->width()) * info.bytesPerPixel());	1	1
233	}	0	0



Security Analysts still need to investigate the whole subgraph pattern to locate the exact vulnerable line

3 Limitations of the IVDetect Approach

- IVDetect only trained on project-specific data

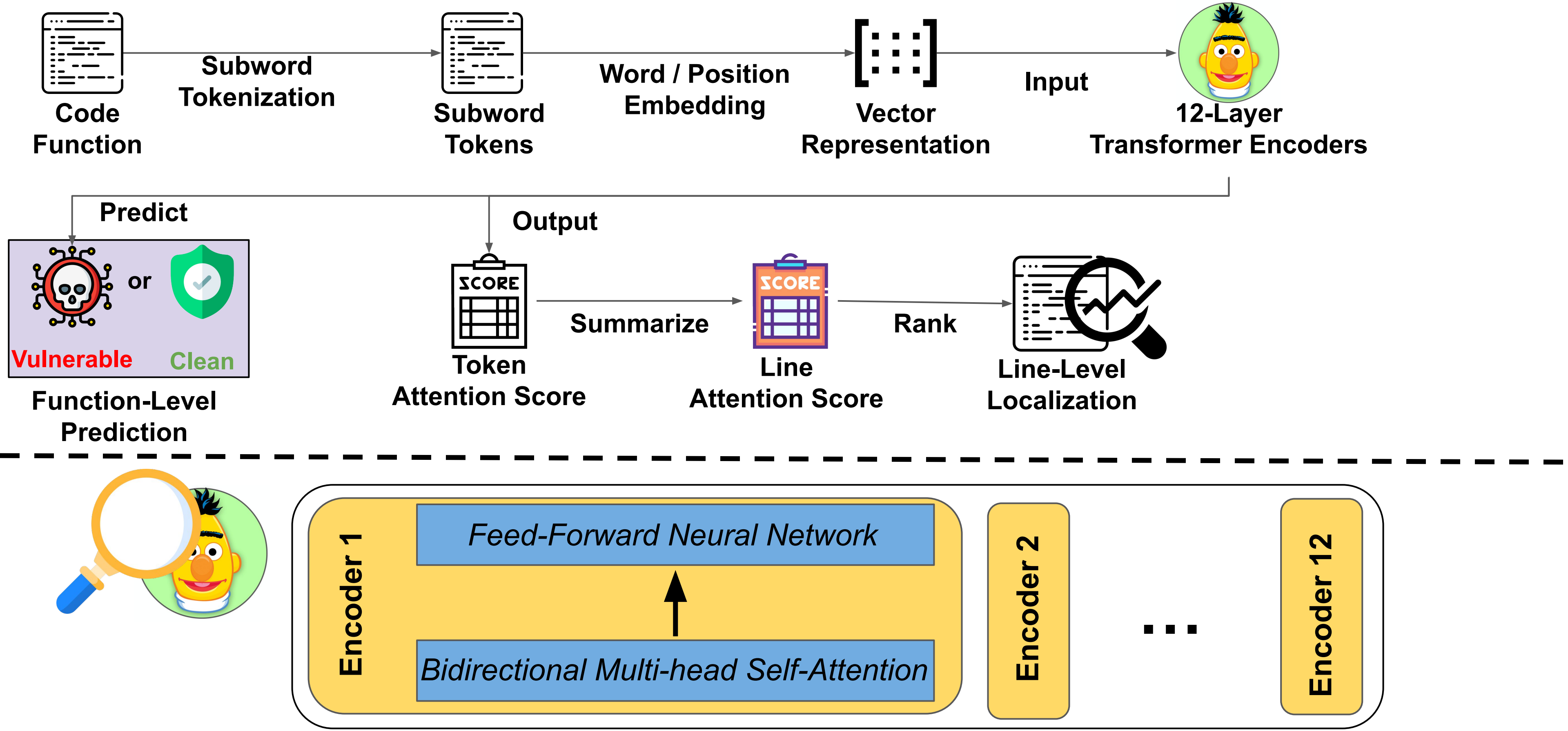
Inaccurate Vulnerability Predictions

- The RNN-based feature extractor of IVDetect is not effective to capture the long-term dependencies of a sequence.

- The subgraph-level vulnerability localization of IVDetect is still coarse-grained

More Effort for the Security Analysts

LineVul: A Transformer-based Line-Level Vulnerability Prediction



Example Line-Level Prediction of LineVul

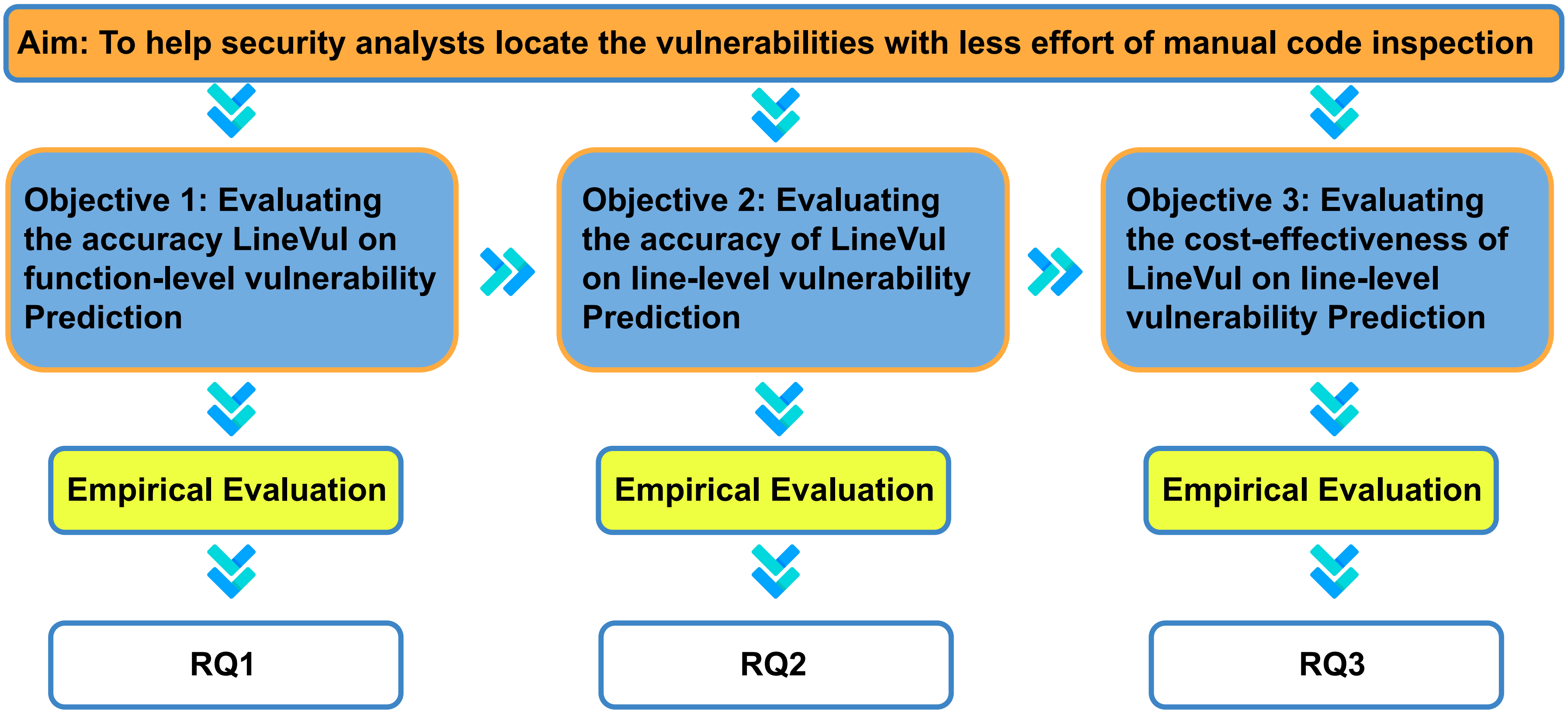
An example prediction of LineVul using real world data

// Line-level Vulnerability Predictions by LineVul				
third_party/WebKit/Source/core/frame/ImageBitmap.cpp https://github.com/chromium/chromium/commit/d59a4441697f6253e7dc3f7ae5caad6e5fd2c778		LineVul	IVDetect	Ground truth
224	static sk_sp<SkImage> unPremulSkImageToPremul (SkImage* input) {	0.8	0	0
225	SkImageInfo info = SkImageInfo::Make(input->width(), input->height(),	0.6	0	0
226	kN32_SkColorType, kPremul_SkAlphaType);	0.5	0	0
227	RefPtr<Uint8Array> dstPixels = copySkImageData(input, info);	0.8	0	0
228	if (!dstPixels)	0.3	**1**	0
229	return nullptr;	0.3	0	0
230	return newSkImageFromRaster(	0.5	**1**	0
231	info, std::move(dstPixels),	0.6	**1**	0
232	static_cast<size_t>(input->width()) * info.bytesPerPixel());	**1**	**1**	1
233	}	0	0	0

Vulnerable Line

Security Analysts are able to locate the exact vulnerable line in a vulnerable function

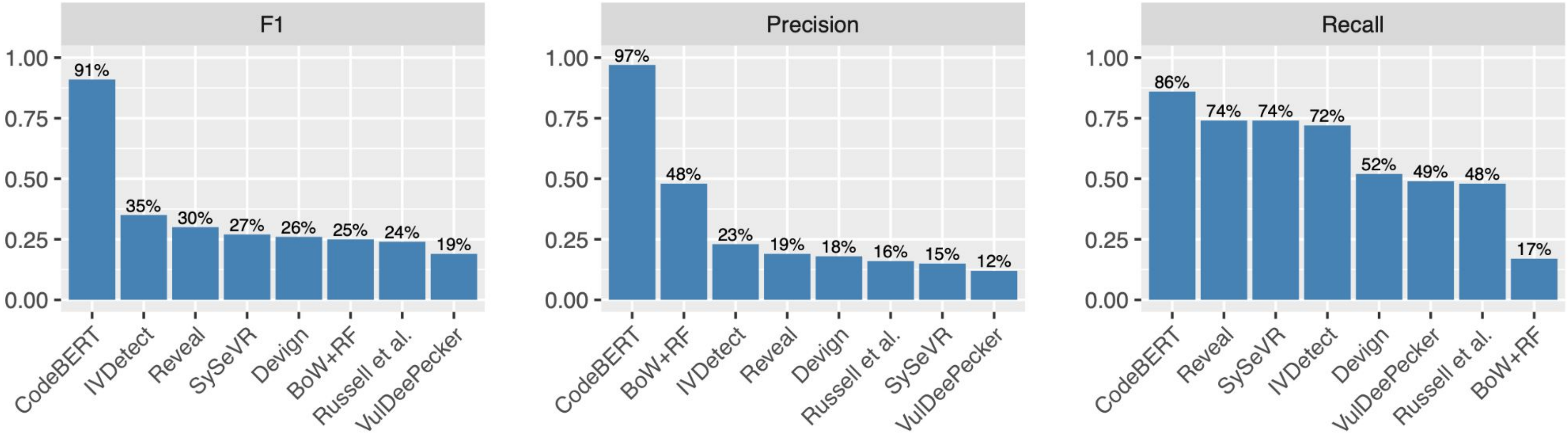
Study Design



RQ1

Function-level

How accurate is our LineVul for function-level vulnerability predictions?



Our LineVul achieves the highest F1-measure, Precision, and Recall when comparing with other baseline models including the SOTA IVDetect.

RQ2

Line-level

How accurate is our LineVul for line-level vulnerability localization?

Metric 1 - Top-K Accuracy

Evaluate the model performance by considering top-k lines in each function after the ranking procedure.

Measure the line-level Precision of the model interpretation approach

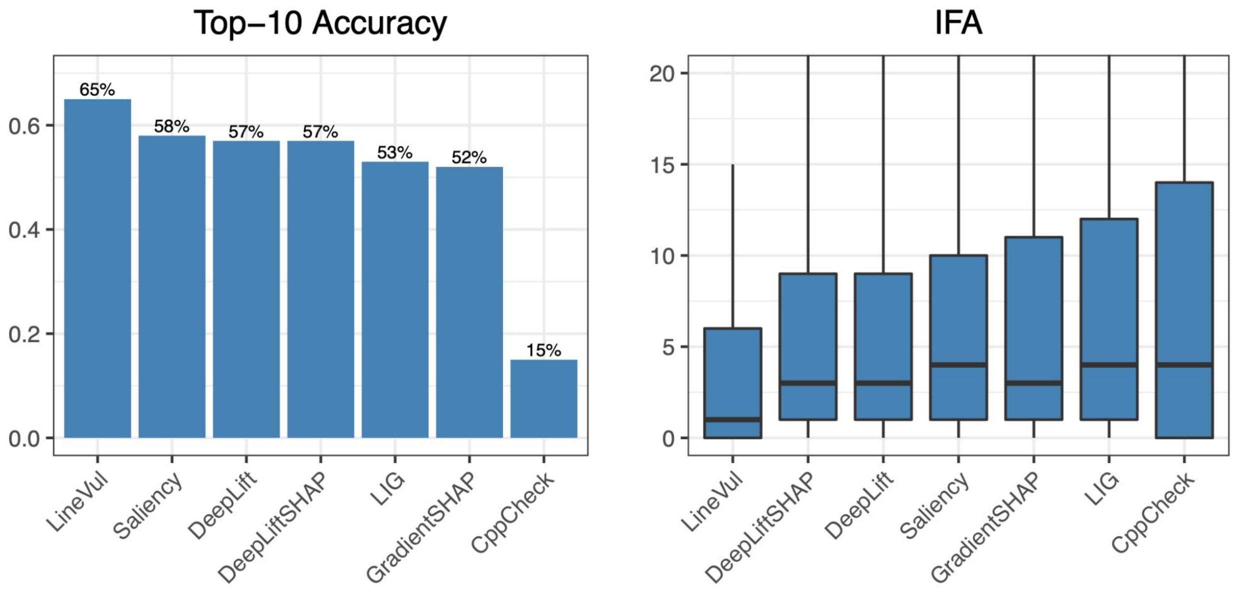
Metric 2 - Initial False Alarm (IFA)

Evaluate how many lines do the model need to include when capturing the first vulnerable line in a function.

RQ2

Line-level

How accurate is our LineVul for line-level vulnerability localization?



The Attention Score Reasoning of LineVul achieves the best Top-10 Accuracy and IFA when comparing with other model interpretation approaches.

RQ3

Line-level

What is the cost-effectiveness of our LineVul for line-level vulnerability localization?

Metric 1 - Effort@K%Recall

The number of inspected LOC when capturing the K% of vulnerable lines divided by the total LOC.

Measure the line-level cost-effectiveness of the model interpretation approach

Metric 2 - Recall@K%LOC

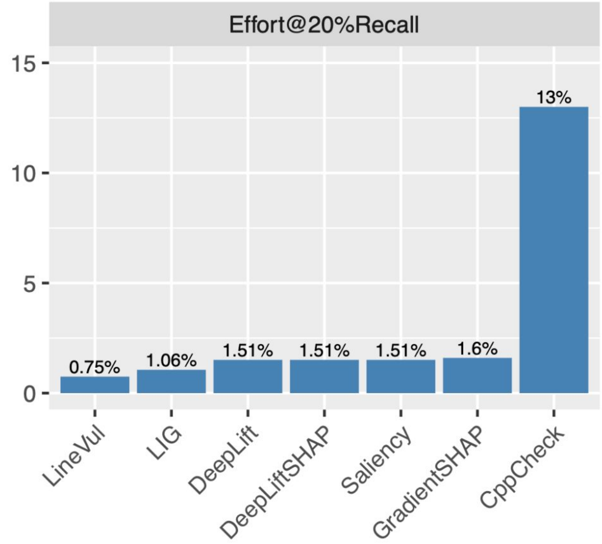
Given a fixed amount of effort (K% LOC), how many vulnerable lines can be captured by the model.

RQ3

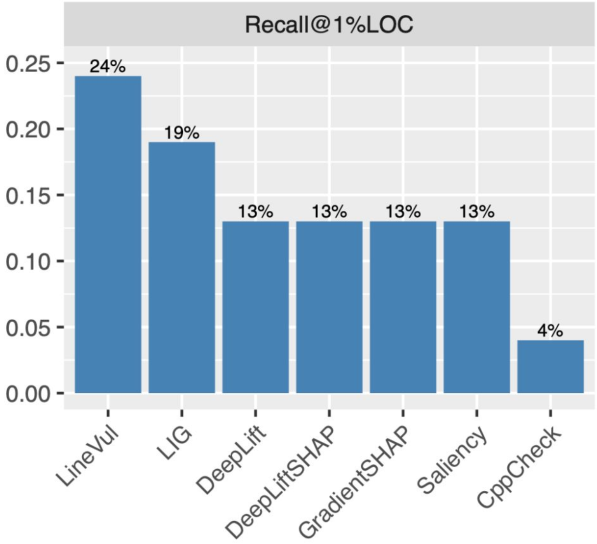
Line-level

What is the cost-effectiveness of our LineVul for line-level vulnerability localization?

Fixed amount of vulnerabilities

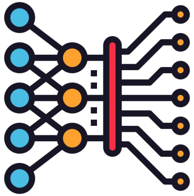


Fixed amount of effort



The Attention Score Reasoning of LineVul achieves the best Effort@20%Recall and Recall@1%Loc when comparing with other model interpretation approaches.

Take-Away Messages



1. Vulnerability Prediction Model is needed to mitigate the challenge of vulnerability detection and help security analysts locate the vulnerable code faster.

2. LineVul is one of the important advancement toward more accurate and finer-grained Vulnerability Prediction.

Thank you very much for your listening

Full Paper:

https://www.researchgate.net/publication/359402890_LineVul_A_Transformer-based_Line-Level_Vulnerability_Prediction

To replicate our LineVul approach:

please go to https://github.com/awsm-research/LineVul

For any issues or collaboration,

please email: yeh.fu@monash.edu