

Memory corruption vulnerabilities: Modern safeguards and their shortcomings

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Abstract—Memory corruption vulnerabilities are a class of software security vulnerabilities that occur when a system’s memory is altered in an unintended way. In many cases, the result of memory corruption is a program crash or unintended behavior; however, many of these bugs can be exploited by malicious actors to gain unauthorized access to the system. Despite the advent of memory-safe languages and considerable effort identifying and fixing the sources of these vulnerabilities in memory-unsafe languages, this class of vulnerability remains one of the most common attack vectors in cyber-systems. Most modern computers include both hardware and operating system features to prevent an attacker from successfully exploiting these bugs, but nevertheless, attackers can bypass many of these protections. This paper discusses common memory corruption vulnerabilities, several modern safeguards to protect cyber-systems, and strategies that can be used to circumvent them.

Index Terms—memory corruption, security, vulnerability, systems, malware

I. INTRODUCTION

As computers have become more embedded in everyday life, the security of these systems has become a critical concern. Cyber attacks against government and non-government organizations has increased in recent years, particularly those targeting healthcare and large, multinational companies [1]. As personal data is increasingly being collected and stored on servers, the scale of these breaches is also increasing. For example, a recent breach of Change Healthcare in 2025 exposed the personal data of more than 192 million individuals in the United States [2].

Despite being recognized as a critical vulnerability over 30 years ago and numerous approaches to mitigate them, memory corruption vulnerabilities are still found in all types of software [3]. Indeed, the 2024 list of the top 25 most dangerous software vulnerabilities included buffer overflows and use-after free in the second and eighth positions, respectively [4]. When exploited, these vulnerabilities can allow for arbitrary code execution, privilege escalation, and information leakage. The financial implications of security vulnerabilities are substantial, and IBM estimated the cost of a data breach in 2025 to be \$4.4 million [5].

In practice, a program is considered memory safe as long as a set of memory errors can never occur [3], though rigorous, formal definitions have been presented in recent years [6]. Memory corruption is due to the lack of memory safety in

low-level languages such as C and C++, and while memory and type safe languages such as Java and Rust provide memory safety, the use of memory-unsafe languages is ubiquitous in systems programming. Additionally, mitigation techniques are not always used, even among modern operating systems. These techniques may require non-existent hardware support on older systems, have large performance costs, or require recompilation of critical components [7].

II. OVERVIEW OF MEMORY CORRUPTION VULNERABILITIES

A. Buffer Overflow Vulnerabilities

B. Use After Free

C. Double Free

D. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
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- Use a zero before decimal points: “0.25”, not “.25”. Use “cm³”, not “cc”.)

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Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{1}$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

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Please use “soft” (e.g., `\eqref{Eq}`) cross references instead of “hard” references (e.g., (1)). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

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- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).

- Do not use the word “essentially” to mean “approximately” or “effectively”.
- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
- Do not confuse “imply” and “infer”.
- The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the “et” in the Latin abbreviation “et al.”.
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Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

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a) *Positioning Figures and Tables:* Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert

TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

^aSample of a Table footnote.



Fig. 1. Example of a figure caption.

figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

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ACKNOWLEDGMENT

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REFERENCES

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