

# A Framework for Assessing Decompiler Inference Accuracy of Source-Level Program Constructs

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**Abstract**—Decompilation is the process of reverse engineering a binary program into an equivalent source code representation with the objective to recover high-level program constructs such as functions, variables, data types, and control flow mechanisms. Decompilation is applicable in many contexts, particularly for security analysts attempting to decipher the construction and behavior of malware samples. However, due to the loss of information during compilation, this process is naturally speculative and thus is prone to inaccuracy. This inherent speculation motivates the idea of an evaluation framework for decompilers.

In this work, we present a novel framework to quantitatively evaluate the inference accuracy of decompilers, regarding functions, variables, and data types. Within our framework, we develop a domain-specific language (DSL) for representing such program information from any “ground truth” or decompiler source. Using our DSL, we implement a strategy for comparing ground truth and decompiler representations of the same program. Subsequently, we extract and present insightful metrics illustrating the accuracy of decompiler inference regarding functions, variables, and data types, over a given set of benchmark programs. We leverage our framework to assess the correctness of the Ghidra decompiler when compared to ground truth information scraped from DWARF debugging information. We perform this assessment over a subset of the GNU Core Utilities (Coreutils) programs and discuss our findings.

## I. INTRODUCTION

### A. Context and Background

In an increasingly digital world, cybersecurity has emerged as a crucial consideration for individuals, companies, and governments trying to protect their information, financial assets, and intellectual property. Of the many digital threats, various forms malware continue to pervade the digital landscape and thus remain a key concern for security analysts. One approach for combating malware involves attempting to deconstruct and reason about the malware itself. Understanding the functionality and behavior of malware samples may aid a security analyst in identifying methods to thwart or disable the malware’s effects on a target system and similar systems.

Although simple in concept, the act of reverse engineering and reasoning about malware proves to be a steep challenge. The primary issue is that access to high-level malware source code is almost never available and, thus, any reasoning about the malware must be derived from the malware sample itself. Another issue is that malware authors often leverage obfuscation techniques to mask the intention and behavior of

malware samples. To evade antivirus tools using signature-based detection, malware authors may employ techniques such as dead-code insertion, register reassignment, subroutine re-ordering, instruction substitution, code transposition, and code integration []. To complicate semantic binary code analysis of malware samples, malware authors may leverage compile-time strategies such as stripping and compiler optimizations []. Although we have discussed these obfuscation strategies in the context of malware, these techniques may be also leveraged by developers or companies attempting to dissuade binary code analysis of proprietary software.

Despite the challenge of binary code analysis, there exist many tools that attempt to glean high-level semantic information from binary code samples. A *disassembler* takes binary code as input and produces architecture-specific assembly code as output. Many challenges and considerations exist in the disassembly process - particularly for stripped binary code - such as discerning code from data and locating function boundaries []. One invariant in the disassembly process, however, is that the mapping from assembly instructions to binary instructions and vice-versa is always one-to-one. A *decompiler* takes this reverse mapping process one step further by translating binary code into an equivalent high-level source code representation. The decompilation process is inherently speculative since high-level information such as function boundaries, variables, data types, and high-level control flow mechanisms are lost when a program is compiled. With this, the decompiler must infer enough high-level structure for useful analysis without being overly aggressive and consequently blurring the program’s intent. Many decompiler tools are currently in use by the reverse engineering community. Commercial decompiler tools include IDA Pro [] and JEB3 []. Popular open-source decompiler frameworks include Ghidra [], RetDec [], and Radare2 [].

### B. Research Problem

Due to the number of decompiler tools as well as the imprecise nature of decompilation, a generalized and extensible quantitative evaluation framework for decompilers is critical. Existing work by Liu and Wang [] proposes an evaluation technique to determine whether recompiled decompiled programs are consistent in behavior to their original binaries. This

technique, although useful, does not offer any insight into the inference accuracy of decompilers with respect to high-level program constructs such as functions, variables, and data types. The inference accuracy of these high-level constructs are important for analysts to gain an understanding of the analyzed program.

### C. Research Objectives

Targeting the current gap in the literature outlined in the previous section, this paper presents a novel framework for quantifying and assessing the accuracy of decompiler tools. To prove our concept, we apply our framework to the Ghidra decompiler and subsequently discuss our findings. The primary objectives achieved by this work are as follows:

- 1) We define a domain-specific language (DSL), written in Python, for expressing high-level program information such as functions, variables, and data types. This serves as a language-agnostic medium whereby we can translate program information extracted from a decompiler or a ground-truth source.
- 2) We extend our DSL to compare program information representations from different sources. A common use case is to compare ground-truth program information to decompiler-inferred program information.
- 3) Leveraging the comparison logic in (2), we define a set of quantitative metrics to measure the accuracy of function, variable, and data type inference.
- 4) We develop a translation module in Python that uses DWARF debugging information from a binary program to generate a ground-truth program information representation in our DSL.
- 5) We utilize the Ghidra Python API to implement a translation module, taking a Ghidra decompilation of a binary program as input and producing a program information representation in our DSL.
- 6) Using our developed language, metrics, and translation modules, we quantitatively assess the accuracy of the Ghidra decompiler when compared to ground-truth program information obtained from DWARF debugging information. We perform this analysis using the set of GNU Coreutils programs as benchmarks. We present the evaluation results and discuss additional findings and takeaways.

### D. Evaluation Summary

We use our evaluation framework to perform an assessment of the Ghidra decompiler (version 10.2) over 105 GNU Core Utilities (version 9.1) benchmark programs compiled with GCC (version 11.1.0). We evaluate Ghidra with no optimizations under three compilation cases of the benchmark programs - (1) stripped, (2) standard (not stripped, no DWARF symbols added), and (3) debug (DWARF symbols included) - to determine how the level of information provided in the binaries affects recovery and inference performance of functions, variables, and data types by Ghidra.

Our function recovery analysis reveals that Ghidra successfully recovers 100% of the 18139 functions under the stripped and standard compilation conditions across all benchmarks. In the debug compilation case, Ghidra successfully identifies all functions but fails to decompile four functions in the *factor* program due to a type resolution error. Upon further analysis, we conclude this is a bug in the Ghidra decompiler.

Analysis of high-level variable recovery shows that the recovery accuracy of variables of primitive data types (char, int, float, pointer) is significantly higher than the recovery accuracy of complex (aggregate) types (array, struct, union), particularly in the stripped and standard compilation cases when no debugging information is present. Overall, we see a partial high-level variable recoveries percentages of 97.1%, 99.2%, and 99.9% for the three compilation cases, respectively. The percentages of exact high-level variable matches for each of the compilation cases are 36.1%, 38.6%, and 99.6%, respectively.

Related to our high-level variable recovery analysis, we perform a "decomposed" variable recovery analysis. For the decomposition, we recursively decompose each variable into a set of primitive variables as they appear in memory. We then perform the comparison and evaluation similar to in the high-level analysis. We show that the partial recovery percentages for each of the stripped, standard, and debug compilation cases are 73.8%, 92.4%, and 98.0%, respectively. The exact match percentages over the decomposed variables are 24.6%, 25.0%, and 98.0% for each of the compilation cases, respectively. The lower recovery accuracy results in this decomposed analysis are explained by the decomposition of the variables with complex types, namely arrays, that are partially or fully missed in the high-level analysis. These variables, when decomposed, result in an increase in the number of total missed variables. Analysis of decomposed variable recovery by data type shows that int (and char) variables are most accurately inferred, followed by pointer variables, with floating-point (float, double) variables showing the lowest recovery accuracy.

We perform a data bytes recovery analysis to determine the total percentage of data bytes that are found and missed across all ground truth variables by the decompiler. We discover that the bytes recovery percentages are 61.3%, 80.6%, and 99.5% for each the stripped, standard, and debug compilation cases, respectively.

Lastly, we perform an evaluation of the Ghidra decompiler's array recovery accuracy. We find that, for each the stripped, standard, and debug compilation cases, 36.2%, 71.6%, and 99.5% of ground truth array varnodes overlap with at least one associated decompiler-inferred array varnode, respectively. We find the average size (in bytes) discrepancies between compared ground truth and the decompiler variables to be 458.6, 239.0, and 9.42 for each of the compilation cases, respectively. With respect to the sizes of the ground truth arrays, the average array size error percentages for the array comparisons in each compilation case are 91.2%, 47.5%, and 11.0%, respectively.

Across our analyses, we observe that there is a clear

relationship between the compilation configuration of the benchmark programs and the recovery accuracy of program constructs by the Ghidra decompiler. We find that, with respect to recovery of program constructs, the debug compilation case far outperforms the standard case, which moderately outperforms the stripped case. However, despite the relatively high recovery accuracy of the Ghidra decompiler in the debug case, we further explore the causes of misses and partial misses in the debug case and find that Ghidra possesses a major limitation in expressing local variables tied to specific lexical scopes. A compiler such as GCC may reuse stack address space for variables associated with non-overlapping and non-nested lexical scopes. This is a problem for the Ghidra decompiler as we observe that all variable declarations are placed at the top level of the function, ultimately preventing these scope-specific variables from being precisely captured. From our manual analysis of the decompiled benchmark programs, we find that this is the cause of the majority of partially missed variables and data bytes in the debug compilation case. This limitation certainly affects the stripped and standard compilation cases as well.

#### E. Contributions

The three key contributions of this work are as follows:

- 1) We develop a novel framework for evaluating decompiler tools based on the recovery accuracy of high-level program constructs, including functions, variables, and data types. This framework includes a domain-specific language (DSL), developed in Python, to represent and compare sources of high-level program information and their association with binary-level constructs. In addition, we devise quantitative metrics for expressing recovery accuracy of program constructs.
- 2) We leverage our framework to perform an in-depth evaluation of the Ghidra decompiler with respect to high-level function, variable, and data type recovery. This evaluation is performed over the GNU Core Utilities programs under three compilation conditions.
- 3) From our evaluation of Ghidra, we discover and discuss the implications of two key issues present in the Ghidra decompiler.

#### F. Outline

The remainder of this paper is outlined as follows: In section 2, we discuss related research and background concepts useful for the understanding of this work. Next, in section 3, we detail our methodology for developing our evaluation framework. In section 4, we present and discuss the results of applying our evaluation framework to the Ghidra decompiler. We conclude in section 5 with a summary of our results, implications of our work, limitations, and future research directions.

## II. BACKGROUND AND RELATED WORK

### A. Software Reverse Engineering, Disassembly, and Decompile

*Software reverse engineering (SRE)* is the process of analyzing a software system with the intention to extract design and

implementation information, particularly in situations where high-level source code is unavailable []. One common use case for this practice is to understand and deconstruct legacy code present in a software system where the source code has been lost. In this scenario, analysts could use SRE to understand this legacy code, determine its behavior, and ultimately decide how to reuse, patch, or replace the code. Another context for the use of SRE is computer security. Malware, or malicious programs, are nearly always present in binary form without their associated high-level source code. An analyst may use SRE to deconstruct the malware's logic, determine its behavior, and identify approaches to neutralize the malware and harden the host system for prevention of future attacks.

To perform SRE on a binary program, a critical first step is *disassembly*. This process takes binary code as input and produces assembly code as output. A key to this process is that binary and assembly instructions are always mapped one-to-one, and thus the main challenges lie in determining function boundaries and differentiating code, data, and metadata. Factors that contribute to these challenges include the following []:

- Data embedded in code regions
- Variable instruction size (on some architectures)
- Indirect branch instructions (the target of a branch instruction is not statically known)
- Functions without explicit 'CALL' references
- Position independent code sequences
- Manually crafted assembly code

The conversion of binary code to assembly code through disassembly is a desirable starting point in the process of SRE. However, program semantics are still often difficult to interpret and reason about at the assembly code level. This difficulty necessitates an even more speculative process, *decompilation*, that takes a binary program as input and produces a high-level source code representation of the input program's semantics, usually in C. Decompilation, therefore, involves the speculative inference of high-level language concepts such as control flow mechanisms, variables, and data types. Decompiler tools rely heavily on the disassembly process as a first step in their analysis, and therefore the challenges affecting disassembly also naturally affect decompilation. Additional factors that obfuscate the accuracy of decompilation are the following:

- Compiler optimizations
- Stripped debugging information and metadata

With these compounding challenges affecting the decompilation process, it is clear that decompiler tools operate under a great degree of nondeterminism and speculation. This fact highlights the need for a common evaluation framework for decompiler tools.

### B. DWARF Debugging Standard

*DWARF* is a debugging file format used by many compilers and debuggers to support source-level debugging for compiled binary programs []. When specified flags (usually '-g') are present at compilation, DWARF-supporting compilers such as

GCC and Clang will write DWARF debugging information to an output binary program or object file. A resulting binary executable can then be loaded into a DWARF-supporting debugger such as GDB to debug the target binary program with references to line numbers, functions, variables, and types in the source-level program. The DWARF standard is source language agnostic, but generally supports equivalent representations for constructs present in common procedural languages such as C, C++, and Fortran. In addition, DWARF is decoupled from any architecture, processor, or operating system. The generalizability of DWARF debugging information makes it a prime candidate for extracting "ground truth" information about a particular binary program, regardless of the specifics of the source language, architecture, processor, or operating system. DWARF is leveraged in this work to scrape ground-truth information about target binary programs. This information is subsequently used to evaluate the accuracy of the output produced by a target decompiler.

### C. Ghidra Reverse Engineering Framework

*Ghidra*, created and maintained by the National Security Agency Research Directorate, is an extensible software reverse engineering framework that features a disassembler, decompiler, and an integrated scripting environment in both Python and Java []. We use the Ghidra decompiler in this work to demonstrate our decompiler evaluation framework.

### D. Related Work

In the 2020 paper *How Far We Have Come: Testing Decompilation Correctness of C Decompilers* by Liu and Wang [], the authors present an approach to determine the correctness of decompilers outputting C source code. They aim to find decompilation errors, recompilation errors, and behavior discrepancies exhibited by decompilers. To evaluate behavioral correctness, they attempt to recompile decompiled binaries (after potential syntax modifications) and use existing dynamic analysis techniques such as fuzzing to find differences in behavior between the recompiled and original programs. The objective of our work differs as we aim to evaluate decompiler inference of high-level structures such as functions, variables, and data types. Accurate inference of high-level structures enables easier understanding of decompiled programs by analysts; however, accurate behavior is also necessary to ensure that the decompiled representation is consistent with the original program. Hence, both of these works evaluate important aspects of decompiler correctness.

The review *Type Inference on Executables* by Caballero and Lin (2016) provides a comprehensive summary of recent literature on techniques used for variable discovery and type inference. In addition, the authors present various software reverse engineering (SRE) tools and frameworks in terms of their inputs, analysis types, output formats, and use cases. In essence, this work surveys the a set of decompiler tools and characterizes them based on their purported capabilities. The purpose of our work, on the contrary, is to objectively

determine the correctness of decompiler tools based on their inference accuracy of high-level program constructs.

## III. METHODOLOGY

In this section, we discuss the design, construction, and evolution of our decompiler evaluation framework. To achieve this, we identify key objectives that we subsequently address in more detail in the following subsections. These objectives are as follows:

- 1) Express program information such as functions, variables, data types, and addresses in a common representation.
- 2) Programmatically capture a "ground truth" representation for a given program.
- 3) Programmatically scrape program information from decompiler tools, namely Ghidra.
- 4) Compare two program representations of the same program.
- 5) Formulate quantitative metrics for evaluating the accuracy of a decompiler.

1) *Domain-Specific Language (DSL) for Program Information*: In order to make our framework general and reusable, we devise a common domain-specific language (DSL) to represent program information such as functions, variables, data types, and addresses, as well as the relationships between them. This DSL must act as a bridge linking binary-level address information with the source-level structures such as functions, variables, and data types. Combining the information from these two layers of abstraction is, in essence, a mapping between binary-level and source-level structures. The accuracy of this mapping for a given decompiler is precisely the objective of our analysis.

[Figure representing how DSL can be constructed from many sources (DWARF, Ghidra, IDA Pro, etc.)]

The DSL we devised is entirely decoupled from the source of the program information. This allows any ground truth or decompiler source of program information to be translated into this common language and subsequently analyzed or compared with another source of program information. The core of our language is defined in Python and is compatible with Python (Jython or CPython) versions  $\geq 2.7$ . We chose Python because the Ghidra framework supports custom Python scripts for querying and manipulating program information obtained from the disassembler and decompiler. In addition, the Python 'pyelftools' open-source library [] allows scraping DWARF debugging information directly from binary programs. This DWARF information can then be utilized to construct a "ground truth" representation of program information. We discuss this further in the next section.

a) *DSL Definitions*: In this section, we briefly describe the structure and relationships of the major constructs that comprise our DSL.

At the root of our DSL is the *ProgramInfo* type. The fields of this type include a list of global variables (*Variable* objects) and a list of functions (*Function* objects).

The *Function* type holds information about a function such as the name, the start PC address (*Address* object), the end PC address (*Address* object), a list of parameters (*Variable* objects), a list of local non-parameter variables (*Variable* objects), and the return type (*DataType* object).

The *Variable* type contains information about a source-level global variable, local variable, or parameter. A variable has a name, a data type (*DataType* object), and a list of address "live ranges". We consider a live range (*AddressLiveRange* type) to be the association of a variable's storage address with the PC address range where the storage location is valid for the variable. This "live range" concept allows for the expression of source-level variables that map to multiple underlying storage locations throughout their lifetime. Multiple live ranges may be associated with a single variable when compiler optimizations are present.

The *Address* type represents any absolute or relative location referenced in a binary program. This could include a PC location, variable storage location, or a register. From an implementation perspective, *Address* is the base class with subclasses representing the different types of address constructions based on context. These *Address* subclasses include *AbsoluteAddress*, *RegisterAddress*, *RegisterOffsetAddress*, and *StackAddress*. Each address is associated with an *AddressRegion*. This type is used to manage ordering and comparison logic for addresses that fall within the same region.

The last main construct in our core DSL is *DataType*. This type represents a source-level data type and is typically associated with a variable or a function return type. *DataType* is the base of a class hierarchy with subclasses representing particular data types. The subclasses include *DataTypeFunctionPrototype*, *DataTypeInt*, *DataTypeFloat*, *DataTypeUndefined*, *DataTypeVoid*, *DataTypePointer*, *DataTypeArray*, *DataTypeStruct*, *DataTypeUnion*. Although these defined types correspond to C-like data types, this language can easily be extended to support other data types present in other high-level programming languages. All data type objects contain a "size" field representing the number of bytes the given data type occupies in memory.

2) *Capturing Ground Truth Program Information*: With our DSL defined, we need a reliable method to extract "ground truth" information from a program and translate this information into our DSL. This "ground truth" information is intended to be used in a comparison with the program information obtained from a decompiler. Our framework is meant for evaluation and therefore we assume that we have access to the source code of benchmark programs to be used for the evaluation. With this assumption, we consider two options for extracting program information from a given source program.

The first option for extracting ground truth information is to parse the source code's abstract syntax tree (AST) and then use this AST to manually extract functions, variables, and data types. There are two major issues with this approach. First, parsing source code to an AST assumes a particular source programming language which greatly reduces generality. Second, obtaining the AST alone does not offer any binary-level

information that allows us to link binary-level addresses with the source-level structures.

The second, more favorable, approach to extracting ground truth program information involves leveraging debugging information optionally included in the binary by the compiler. The primary purpose of debugging information is to link binary-level instructions and addresses with source-level structures. This binary-level to source-level association is precisely what is needed to translate program information into our DSL. Since our framework is developed and targeted at Linux, we choose the DWARF debugging standard as the assumed debugging format for our framework. However, defining a translation module from another debugging format into our DSL is certainly possible and is an idea for future work. The DWARF debugging standard is supported by nearly all major Linux compilers and supports any source programming language (with possible extensions). These properties of the DWARF standard allow it to be used as a "ground truth" source of program information, decoupled from the source language or the compiler.

a) *Translating DWARF to the DSL*: Starting with a source-level program, we must perform the following steps to extract program information represented in our DSL. First, we compile the source program with the option to include debugging symbols. In our particular analysis we use the GCC compiler specifying the "-g" flag. Many other compilers also offer the option for compilation with the inclusion of DWARF debugging symbols. After we compile the program, we then extract the DWARF debugging information from the resulting binary. We utilize the 'pyelftools' Python library [ ] to perform this extraction. The extraction results in, among other information, a set of debugging information entries (DIEs). Together, these DIE records provide a description of source-level entities such as functions, variables, and data types in relation to low-level binary information such as PC addresses and storage locations. Each DIE contains the following important features:

- An *offset* uniquely identifying the DIE within its compilation unit. These offsets are how DIEs reference other DIEs.
- A *tag* representing the "class" of the DIE. Example tags include "DW\_TAG\_subprogram", "DW\_TAG\_variable", and "DW\_TAG\_base\_type".
- A set of *attributes* specifying tag-specific properties of the DIE. Examples include "DW\_AT\_name", "DW\_AT\_size", and "DW\_AT\_type".

The translation process from the DIE graph into our DSL is, at its core, a process of forming a nested data structure (our DSL's *ProgramInfo* type) from a flattened one (a collection of DWARF DIEs). To tackle this translation, we first define an intermediate representation (IR) language that acts as a "flattened" analog to the constructs present in our DSL. Instead of each IR construct directly containing the fields of other constructs, they instead contain fields that reference the IDs of other constructs through a shared database. The responsibility of the database is to map unique IDs to the flattened constructs. When all the IR constructs have been inserted

into the database, the database then recursively resolves the flattened IR structures into their associated DSL structures, starting from the root *ProgramInfoStub* object, the IR analog to the *ProgramInfo* DSL type. This process is complicated by the fact that some data types, particularly *struct* types, may be recursive or mutually recursive, ultimately creating a cycle in the reference resolver. To address this, we implemented a mechanism whereby each IR node is marked when it is visited. Future attempts to resolve the same IR construct return with the existing object being resolved instead of attempting to resolve the same reference again. With the IR defined and the resolution logic in place, we map the DWARF DIE objects into our "flattened" IR and construct the IR object database. When all the DIEs are processed and translated, we specify the *ProgramInfoStub* node as the root reference and then execute our resolver algorithm to recursively generate the *ProgramInfo* object and subobjects defined in our DSL. Our DWARF translation module consists of about 1000 lines of Python code. The IR and resolver logic adds an additional 600 lines of code.

[DWARF parsing figure: DIEs  $\rightarrow$  IR  $\rightarrow$  DSL]

3) *Capturing Decompiler Program Information*: In addition to capturing a ground-truth program representation in our DSL, we must construct a DSL representation of the program information obtained from a decompiler we wish to evaluate. Depending on the decompiler and the structure of its output, this process may take many forms, often involving querying APIs exposed by the decompiler framework. In all cases however, this shall involve defining a translation module from the decompiler output to the structures defined in the DSL. Hence, our framework can be employed on any decompiler assuming a translation module implementation.

a) *Translating Ghidra Decompiler Output to the DSL*: For our analysis of the Ghidra decompiler, we utilize the Ghidra scripting API to programmatically scrape and process information about the decompilation of target binary programs. The Ghidra scripting environment exposes its own collection of data structures and functions from which we obtain our information. Since the Ghidra scripting environment supports Python, we directly import and leverage our "flattened" IR (described in the previous section) and our DSL constructs to carry out the translation.

The strategy employed for the Ghidra translation is similar to that of our DWARF translation algorithm described in the previous section. We utilize the Ghidra API to obtain particular information about functions, variables, data types, and associated addresses gathered during the decompilation. Of particular use to our translation logic is the *DecompInterface* object exposed by the Ghidra API. This interface supports decompiling functions one at a time. Information inferred by each function's decompilation is used to update Ghidra's internal representation of the program information. By decompiling each of the functions extracted from Ghidra's disassembly analysis, we attempt to form a complete decompiled interpretation of the entire input program.

We use the same IR defined for the DWARF translation to

accumulate flattened records corresponding to these program constructs in a database. From here, we run the same resolution algorithm on the IR constructs database to generate the root *ProgramInfo* object in our DSL. The Ghidra-specific translation logic is implemented in roughly 900 lines of Python code.

4) *Comparison of "Ground Truth" and Decompiler Program Information*: After converting both the ground-truth and decompiler program information into our DSL representation, we next formulate and implement a strategy to compare the two resulting *ProgramInfo* objects. To achieve this, we create an extension of our DSL that defines data structures and functions for capturing comparison information at different layers.

a) *Data Type Comparison*: Given two *DataType* objects and an offset between their start locations, we devise a method to capture nuanced information about the comparison of the data types.

We define the *metatype* of a data type to be general "class" of the given data type. These metatypes include *INT*, *FLOAT*, *POINTER*, *ARRAY*, *STRUCT*, *UNION*, *UNDEFINED*, *VOID*, and *FUNCTION\_PROTOTYPE*. We consider *INT*, *FLOAT*, *POINTER*, *UNDEFINED*, and *VOID* to be *primitive metatypes* since they cannot be decomposed further. *ARRAY*, *STRUCT*, and *UNION* are considered *complex metatypes* since these types are formed via the composition or aggregation of different members or subtypes. We consider the 'char' data type to be of the *INT* metatype with size equal to one byte.

[Figure: Ariste type lattice]

A *primitive type lattice* [] is used to hierarchially relate primitive data types based on their metatype, size, and signedness (if applicable). More general types are located higher in the lattice while more specific types are located closer to the leaves. A type lattice may be used to determine whether two primitive data types are equivalent or share a common parent type.

[Figure: Subset relationship example(s)]

We next define a *subset* relationship between two data types. For a given complex data type X and another data type Y with a given offset (possibly 0) between the location of X and Y in memory, Y is considered a *subset* type of X if Y is equivalent to a "portion" of X, consistent with the offset between X and Y. For example, if X is an array, any sub-array or element of X such that elements are aligned and the element types are equivalent to X is considered a subset of X. If X is a struct or union, any sub-struct or member with proper alignment and equal constituent elements is considered a subset of X.

Suppose we have two *DataType* objects X (ground truth) and Y (decompiler) with offset k from the start of X to the start of Y. The goal is to compute the *data type comparison level* for the given comparison. The possible values for the comparison level are as follows, from lowest equality to highest equality:

- \* *NO\_MATCH*: No relationship could be found between X and Y.
- \* *SUBSET*: Y is a subset type of the complex type X.
- \* *PRIMITIVE\_COMMON\_ANCESTOR*: In the primitive type lattice, primitive types X and Y share a common ancestor

type. \* *MATCH*: All properties of X and Y match including metatype, size, and subtypes (if applicable).

We first check the equality of X and Y. If X and Y are equal, we assign the *MATCH* comparison code. In the case that X and Y are both primitive types, we attempt to compute their shared ancestor in the primitive type lattice. If a common ancestor could be found, we assign *PRIMITIVE\_COMMON\_ANCESTOR*. If X is a complex type, we employ an algorithm to determine whether Y is a subset of X at offset k by recursively descending into constituent portions of X starting at offset k (sub-structs, sub-arrays, elements, members) and checking for equality with Y. If a subset relationship is found, we assign the *SUBSET* compare level. In all other cases, we assign the *NO\_MATCH* compare level.

b) *Variable Comparison*: There are two main contexts where variable comparison occurs. The first context is at the top level, where the set of ground-truth global variables is compared to the set of decompiler global variables. The second context for variable comparison is within the context of a function when we compare parameters or local variables between the ground-truth and the decompiler. In either case, comparing sets of variables starts with the decomposition of each *Variable* object from the DSL into a set of *Varnode* objects in our extended DSL.

A *Varnode* ties a *Variable* to a specific storage location and the range of PC addresses indicating when variable lives at that location. The varnodes for a given variable are directly computed from the variable's live ranges discussed previously. In unoptimized binaries, it is the case that a single *Variable* shall decompose into a single *Varnode*.

With each variable decomposed into its associated varnodes, we next partition the varnodes from each the ground-truth and the decompiler based on the "address space" in which they reside. These address spaces include the *absolute* address space, the *stack* address space, and the *register offset* address space (for a given register). The *stack* address space is a special case of the *register offset* address space where the offset register is the base pointer which points to the base of the current stack frame.

For the set of varnodes in each address space, we first order them based on their offset within the address space. Next, we attempt to find overlaps between varnodes from the two sources based on their location and size. If an overlap occurs between two varnodes, we compute a data type comparison taking into account the offset between the start locations of the two varnodes. The data type comparison approach is described in the previous section.

Based on the overlap status and data type comparison of a ground-truth varnode X, one of the following *varnode comparison levels* will be assigned:

- *NO\_MATCH*: X is not overlapped with any varnodes from the other source.
- *OVERLAP*: X overlaps with one or more varnodes from the other space, but the data type comparisons are level *NO\_MATCH*.

- *SUBSET*: X overlaps with one or more varnodes and each of its compared varnodes has data type comparison level equal to *SUBSET*. In other words, the compared varnode(s) make up a portion of X.
- *ALIGNED*: For some varnode Y from the other source, X and Y share the same location and size in memory; however, the data types of X and Y do not match. The data types comparison could have any compare level less than *MATCH*.
- *MATCH*: For some varnode Y from the other source, X and Y share the same location and size in memory, and their data types match exactly.

The inference of variables with complex data types including structs, arrays, and unions proves to be a major challenge for decompilers. Recognizing this, we develop an approach to compare the sets of ground truth and decompiler variables (varnodes) in their most "decomposed" forms. An analysis of this sort helps to recognize how well a decompiler infers the primitive constituent components of complex variables. Furthermore, this allows us to recognize the aggressiveness and accuracy of complex variable synthesis from more primitive components.

[Figure: Example of "decomposing" complex varnode]

We first implement an approach to recursively strip away the "complex layers" of a varnode to its most primitive decomposition. This primitive decomposition produces a set of one or more primitive varnodes. For example, an array of elements is broken down into a set of its elements (decomposed recursively). A struct is broken down into a set of varnodes associated with each of its members (decomposed recursively). Unions present a special case since the members share a common, overlapping region of memory. Hence, to decompose a union, we transform it into an *UNDEFINED* primitive type with the same size as the union.

We apply this primitive decomposition to each varnode in the sets of ground truth and decompiler varnodes. With the two sets of decomposed varnodes, we leverage the same variable comparison approach described previously to compare the varnodes in these sets. The resulting comparison information is treated as a separate analysis from the unaltered varnode sets.

c) *Function Comparison*: The first step in function comparison is to determine whether each ground-truth function is found by the decompiler. We first order the functions from each source by the start PC address of the function. Next, we attempt to match the functions from the two sources based on start address. Any functions from the ground-truth that are not matched by a decompiler function are considered "missed". Functions that are found by the decompiler but absent from the ground-truth are considered "extraneous". For any missed functions, we consider its associated parameters, local variables, and data types to also be "missed".

For each "matched" function based on start PC address, we compute and store information including the return type comparison, parameter comparisons, and local variable com-

parisons. These sub-comparisons leverage the data type and variable comparison techniques described previously.

5) *Quantitative Evaluation Metrics*: In this section, we define quantitative metrics for evaluating the accuracy of the a given decompiler when compared to a ground-truth source. We rely on the function, variable, and data type comparison information discussed previously to extract these metrics. In the following sub-sections, we define sets of metrics that associated with tables seen in our evaluation results section.

a) *Functions*: This set of metrics outlines the function identification performance of the decompiler.

- *Ground truth functions*: The number of functions present in the ground truth program representation.
- *Functions found*: The number of functions from the ground truth set that are identified by the decompiler.
- *Functions missed*: The number of functions from the ground truth set that are not identified by the decompiler.
- *Functions recovery fraction*: The fraction of ground truth functions found by the decompiler divided by the number of ground truth functions.

b) *Varnodes*: Recall that a *Varnode* is defined to be a source-level *Variable* tied to a single storage location for a range of PC addresses. In analyses of unoptimized binaries, the mapping of variables to varnodes is one to one. This set of metrics illustrates the decompiler’s accuracy in recovering varnodes.

- *Ground truth varnodes*: The total number of varnodes present in the ground truth source. This includes varnodes associated with global and local variables from all functions.
- *Varnodes matched @ level LEVEL*: Each ground truth varnode is associated with a *varnode comparison level* (*NO\_MATCH*, *OVERLAP*, *SUBSET*, *ALIGNED*, *MATCH*) during the comparison with the set of decompiler varnodes. This metric specifies the number of ground truth varnodes that are matched at the specified level.
- *Varnodes average comparison score*: For each *varnode comparison level*, we first linearly assign an integer representing the strength of the varnode comparison (*NO\_MATCH* = 0, *OVERLAP* = 1, *SUBSET* = 2, *ALIGNED* = 3, *MATCH* = 4). We then normalize these scores to fall within the range zero to one. Then, for each ground truth varnode, we compute this normalized score. We take the average score over all ground truth varnodes to obtain the resulting metric. This metric approximates how well, on average, the decompiler infers the ground truth varnodes.
- *Varnodes fraction partially recovered*: The fraction of ground truth varnodes with a match level greater than *NO\_MATCH*.
- *Varnodes fraction exactly recovered*: The fraction of ground truth varnodes with a match level equal to *MATCH*.

We repeat this varnode analysis for the decomposed (primitive) set of varnodes resulting from recursively decomposing each of the high-level varnodes into its most primitive set of varnodes. We also repeat our analysis of the original set of varnodes filtered by metatype. The metatypes considered are *INT*, *FLOAT*, *POINTER*, *ARRAY*, *STRUCT*, and *UNION*. Lastly, we repeat the analysis of the decomposed varnodes when filtered by metatype. For this metatype analysis over the decomposed varnodes, we only consider the primitive metatypes *INT*, *FLOAT*, and *POINTER* since the varnodes are guaranteed to be primitive.

c) *Data Bytes*: These metrics look at the total number of data bytes from all variables recovered by the decompiler when compared to the ground truth source.

- *Ground truth data bytes*: The total number of data bytes captured from the ground truth source, derived from all global and local variables.
- *Bytes found*: The total number of data bytes recovered by the decompiler that overlap with data bytes found in the ground truth.
- *Bytes missed*: The number of data bytes present in the ground truth that were not recovered by the decompiler.
- *Bytes recovery fraction*: The fraction of ground truth data bytes found by the decompiler divided by the total number of ground truth bytes.

d) *Array Comparisons*: In this set of metrics, we aim to evaluate the accuracy of the array inference performed by the decompiler. We examine each array comparison made during the comparison of the ground truth with the decompiler and observe the discrepancies in length, size (bytes), dimensions, and element type. The following metrics are presented:

- *Ground truth varnodes (metatype=ARRAY)*: The number of ground truth varnodes with metatype of *ARRAY*.
- *Array comparisons*: The number of array comparisons made when comparing the ground truth with the decompiler. The decompiler may infer 0 or more array varnodes for each given ground truth array varnode.
- *Array varnodes inferred as array*: This measures how many ground truth array varnodes are compared to at least 1 decompiler-inferred array varnode.
- *Array varnodes inferred as array fraction*: Equivalent to *Array varnodes inferred as array* divided by *Ground truth varnodes (metatype=ARRAY)*. This expresses the fraction of ground truth array varnodes that are associated with at least one decompiler array inference.
- *Array length (elements) average error*: For each array comparison, we find the absolute difference in the number of elements inferred by the decompiler as compared to the ground truth. We then average these differences over all array comparisons to arrive at this metric.
- *Array length (elements) average error ratio*: For each array comparison, we first find the absolute difference in the number of elements inferred by the decompiler as compared to the ground truth. We then divide this error by the length of the ground truth array to get the error as



a ratio of the array size. The average of these ratios over all array comparisons produces this metric.

- *Array size (bytes) average error*: This metric is similar to *Array length (elements) average error* but measures the error in bytes instead of number of elements.
- *Array size (bytes) average error ratio*: This metric is similar to *Array length (elements) average error ratio* but computes the error in bytes instead of array elements.
- *Array dimension match score*: This metric is the number of array comparisons where the decompiler inferred the correct number of dimensions divided by the total number of array comparisons.
- *Array average element type comparison score*: Each *data type comparison level* is first mapped to an integer as follows: *NO\_MATCH* = 0, *SUBSET* = 1, *PRIMITIVE\_COMMON\_ANCESTOR* = 2, *MATCH* = 3. We then normalize these values such that the range is scaled from 0 to 1. We refer to this as the *data type comparison score*. Then, for each array comparison, we compute the *data type comparison score* and subsequently average the scores across all array comparisons to generate this metric.

#### IV. EVALUATION

To demonstrate our evaluation framework, we target the Ghidra decompiler (version 10.2). We use the GNU Core Utilities programs (version 9.1) as our set of benchmarks. For each of the benchmark programs, we evaluate the accuracy of Ghidra decompilation with the program compiled in three ways: (1) stripped, (2) standard (not stripped, no debugging symbols), and (3) DWARF debug symbols included. We use the results from each of these cases to discern how the amount of information included in the binary affects the Ghidra decompiler’s inference accuracy. To limit the scope of our analysis, we only consider unoptimized binaries. We use the GCC compiler (version 11.1.0) to compile the benchmark programs. The architecture and operating system of the testing machine are x86-64 and Ubuntu Linux (version 20.04), respectively.

##### A. Setup

Prior to evaluation, we compile the 105 Coreutils benchmark programs with three compilation configurations: (1) stripped, (2) standard (not stripped, no debugging symbols), and (3) DWARF debug symbols included. For each program, we first extract the ground truth information from the binary with DWARF symbols included via our DWARF translation module. We then use our Ghidra translation module to extract the Ghidra decompilation information from the binaries compiled under each of the compilation configurations. At this point, all program information from the DWARF and Ghidra sources are represented as *ProgramInfo* objects in our DSL.

Next, for each program, we perform a comparison of the program information scraped from DWARF (from the “debug” binary including DWARF symbols) with the information obtained from the Ghidra decompilation of the programs under

TABLE I  
SUMMARY OF FUNCTION RECOVERY BY COMPILATION CASE

	Ground truth functions	Functions found
strip	18139	18139
standard	18139	18139
debug	18139	18135

each of the compilation configurations. The information from these comparisons are expressed in the form of objects which contain comparison information about functions, variables, and data types compared between the DWARF and Ghidra sources.

With the comparisons computed for each program and compilation configuration, we use these comparisons to compute high-level metrics that summarize the performance of the Ghidra decompiler with respect to the given benchmarks and compilation configurations (stripped, standard, and debug).

##### B. Function Recovery

Tables XX, YY, and ZZ in the appendix present function recovery metrics of each benchmark program under the three compilation configurations. Table AA shows the summarization of the recovery statistics accumulated over all benchmark programs. We find that over the 18139 functions present in the ground truth, the stripped and standard compilation cases produce 100% function recovery while the debug case fails to recover four functions, resulting in a 99.9% recovery rate. Upon examination of table ZZ in the appendix, we find that all four functions missed are from the *factor* program.

To determine the cause of the missed functions, we further investigate the Ghidra decompilation of *factor* and find that each of the missed functions results in a decompilation error, “Low-level Error: Unsupported data-type for ResolveUnion”. This indicates that an error occurred when attempting to resolve a union data type within the decompilation of these functions. Since this error only occurs in the debug compilation case, it is clear that Ghidra’s parsing and interpretation of DWARF information contributes to this error. This same union data type causing the error is successfully captured and represented in our ground truth program information and, thus, this is likely a bug within Ghidra’s resolution logic.

In summary, we see that Ghidra successfully finds all functions for all compilation configurations. However, in the debug case, Ghidra’s attempt to interpret and utilize DWARF information to resolve a union data type in the *factor* program results in a decompiler error for four functions. This error indicates a bug in Ghidra’s DWARF parsing or union resolution logic.

##### C. High-Level Variable (Varnode) Recovery

To evaluate the variable (varnode) recovery accuracy of the Ghidra decompiler, we first measure the inference performance of high-level varnodes, including varnodes with complex and aggregate types such as arrays, structs, and unions. We further measure the varnode inference accuracy by metatype to decipher which of the metatypes are most

TABLE II  
SUMMARY OF DECOMPOSED VARNODE RECOVERY BY COMPILATION CASE

	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVER- LAP	Varnodes matched @ level SUBSET
strip	139776	31280	0
standard	40187	56605	0
debug	10547	128	0

TABLE IV  
SUMMARY OF HIGH-LEVEL VARNODE RECOVERY BY COMPILE CASE

Varnodes @ level 1	Varnodes @ level 2	Varnodes @ level 3	Varnodes @ level 4	Varnodes @ level 5	Varnodes @ level 6	Varnodes @ level 7	Varnodes @ level 8
1000	131593	1662	0.585978	1001	0.738206	18570	
249	133597	1450	0.703095	613	0.924732	19029	
23	523236	52	0.980064	24	0.980246	7	

TABLE III  
SUMMARY OF HIGH-LEVEL VARNODE RECOVERY BY COMPILATION CASE  
AND METATYPE

		Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched level	Varnode comparison score @ 0.860, followed closely by <i>ARRAY</i> and <i>UNION</i> (0.849850), for both the stripped and stan-	Varnode comparison score [0,1]	Varnodes fraction pa recovered
strip	INT	66	48	0	standard compilation cases, the complex (aggregate) metatypes,	0.849850	0.996857
	FLOAT	0	56	0	<i>ARRAY</i> , <i>STRUCT</i> , and <i>UNION</i> show the low recovery	0.631900	1.000000
	POINTER	53	4	0	accuracy with respect to varnode comparison score. Among	0.838952	0.994364
	ARRAY	729	597	565	the primitive metatypes, <i>FLOAT</i> shows the worst recovery	0.315248	0.659027
	STRUCT	152	955	432	metrics for these two compilation cases.	0.419287	0.925307
	UNION	0	2	4		0.625000	1.000000
standard	INT	23	48	0	The debug compilation case demonstrates high relative	0.851374	0.998905
	FLOAT	0	56	0	recovery accuracy across varnodes of all metatypes when	0.632199	1.000000
	POINTER	44	4	0	compared to the stripped and standard cases. Of the primitive	0.859853	0.995321
	ARRAY	181	578	352	metatypes, varnodes of the <i>FLOAT</i> metatype are perfectly	0.560074	0.999509
	STRUCT	1	762	257	recovered while varnodes of the <i>INT</i> and <i>POINTER</i> metatypes	0.625000	1.000000
	UNION	0	2	4		0.998389	0.999381
debug	INT	13	27	0	show exact recovery percentages of 99.8% and 99.9% respec-	0.999654	0.999681
	FLOAT	0	0	0	tively. The complex (aggregate) metatypes, on average, display	0.986085	0.997661
	POINTER	3	0	0	slightly lower recovery metrics than the primitive metatypes	0.990000	0.999017
	ARRAY	5	17	24	in the debug compilation case. The <i>ARRAY</i> metatype reveals	0.990000	1.000000
	STRUCT	2	8	0			
	UNION	0	0	0			

and least accurately inferred by the decompiler. This analysis is performed under each compilation configuration (stripped, standard, and debug).

Tables XX, YY, and ZZ in the appendix show the inference of high-level varnodes for each benchmark compiled with each of the compilation configurations. This data is summarized in table AA. We find that Ghidra at least partially infers 97.2%, 99.3%, and 99.6% and precisely infers 36.1%, 38.6%, and 99.7% of high-level varnodes for each for the stripped, standard, and debug compilation cases, respectively. In addition, the varnode comparison scores for each compilation case are 0.788, 0.816, and 0.998, respectively. These metrics indicate that the standard compilation case slightly outperforms the stripped case in varnode inference while the debug compilation case results in significant improvements over both the stripped and standard cases, particularly in exact varnode recovery.

In tables XX-XX, YY-YY, and ZZ-ZZ, we show the inference performance of high-level varnodes for each benchmark, broken down by the metatype of the ground truth varnodes, and for all compilation configurations. We summarize this information in table BB. From the stripped and standard compilation cases, we observe that varnodes with metatype *INT* are most accurately recovered when considering varnode comparison score, fraction partially recovered, and fraction exactly recovered. In the stripped case, the inference of *AR*-

Metatype	Standard	Stripped
RAY	0.315	0.11
STRUCT	0.0	0.0
ARRAY	0.0	0.0
UNION	0.0	0.0
FLOAT	0.0	0.0
PRIMITIVE	0.0	0.0

The debug compilation case demonstrates high relative recovery accuracy across various nodes of all metatypes when compared to the stripped and standard cases. Of the primitive metatypes, varnodes of the *FEAT* metatype are perfectly recovered while varnodes of the *INT* and *POINT* metatypes show exact recovery percentages of 99.8% and 99.9% respectively. The complex (aggregate) metatypes, on average, display slightly lower recovery metrics than the primitive metatypes in the debug compilation case. The *ARRAY* metatype reveals

the worst varnode comparison score at 0.986. The *UNION* metatype demonstrates the lowest exact match percentage at 87.5%.

#### D. Decomposed Variable (Varnode) Recovery

In this section, we repeat a similar varnode recovery analysis over all varnodes; however, we first recursively decompose each varnode into a set of primitive varnodes (see section XX). We perform this analysis over all benchmarks for each of the three compilation cases.

Similar to the high-level varnode analysis, we show the inference of the decomposed varnodes for each benchmark and for each compilation configuration in appendix tables XX, YY, and ZZ. Table AA summarizes this information. Naturally, we expect to see lower recovery metrics compared to the high-level varnode analysis since each complex varnode is now analyzed as a set of its constituent parts. Hence, a single "missed" high-level varnode is translated into a set of primitive varnodes, each "missed" in this analysis. We find this hypothesis to hold true across all compilation cases as each the varnode comparison score, varnodes fraction partially recovered, and varnodes fraction exactly recovered show lower values than in the high-level analysis. We see that the decomposed varnode comparison scores for the strip, standard, and debug compilation cases are 0.586, 0.703, and 0.980, respectively. The varnodes fraction partially recovered are 73.8%, 92.5%, and 98.0% while the varnodes fraction

TABLE V  
SUMMARY OF DECOMPOSED VARNODE RECOVERY BY COMPILATION CASE  
AND PRIMITIVE METATYPE

		Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	
strip	INT	132910	28812	0
	FLOAT	72	73	0
	POINTER	6725	2057	0
standard	INT	40017	46846	0
	FLOAT	0	145	0
	POINTER	132	9245	0
debug	INT	10533	124	0
	FLOAT	0	0	0
	POINTER	14	2	0

exactly recovered are 24.7%, 25.0%, and 98.0% across the compilation cases, respectively. Interestingly, in the stripped compilation case, we find that the number of "missed" decomposed varnodes (139937) exceeds the number of "exactly matched" decomposed varnodes (131719). This is largely due to the quantity of high-level *ARRAY* and *STRUCT* varnodes that are missed in the stripped case.

We split the decomposed varnodes by metatype and show these results in tables XX-XX, YY-YY, and ZZ-ZZ. We present the summary of these results over each compilation case in table BB. The table shows that the stripped and standard compilation cases demonstrate the poorest inference performance in terms of varnode comparison score for varnodes of metatype *FLOAT*. However, we find that the percentage of "missed" *INT* varnodes is worse than that of *FLOAT* in the standard and debug compilation cases, and is nearly the same in the stripped case. This may be explained by the prevalence of integer (or character) arrays in the Coreutils benchmark programs when compared to other array types. Recovery accuracy of the *POINTER* metatype is comparable to the *INT* metatype across the three compilation cases.

#### E. Data Bytes Recovery

Following from our varnode inference analysis, we next assess the accuracy of the Ghidra decompiler with regards to the total number of data bytes recovered across all varnodes. This analysis provides an important perspective on data recovery as the size of an improperly inferred varnode may result in a wide range in the number of misinferred bytes. For example, a large array and a single character are each represented by a varnode, but the quantity of data present in the array is much greater than that of a character. Hence, it is important to capture this nuanced view of data recovery.

In tables XX, YY, and ZZ, we show the data bytes recovery metrics for each of the benchmark programs under each compilation case. We summarize the data bytes recovery for each of the compilation cases in table AA. We see that Ghidra recovers 61.3%, 80.6%, and 99.5% of data bytes in the stripped, standard, and debug compilation cases, respectively.

#### F. Array Inference Accuracy

The last major analysis we perform targets the array inference accuracy of the Ghidra decompiler. We aim to measure metrics regarding the total number of arrays inferred, the lengths and size discrepancies of compared arrays, and the similarity of element types of compared arrays. We perform this analysis across the Coreutils benchmarks and for each compilation configuration, resulting in tables XX-YY and ZZ located in the appendix. This information is summarized in table AA, broken down by compilation configuration.

Across all benchmarks, there are 2138 ground truth arrays present. For each the stripped, standard, and debug compilation cases, the number of ground truth arrays recognized as arrays by the decompiler are 774 (36.2%), 1530 (71.6%), and 2128 (99.5%), respectively. We see that the numbers of array comparisons for each compilation case are greater than these metrics indicating that Ghidra infers some ground truth arrays to be more than one array.

From the array comparisons, we observe that the average absolute differential in array length (number of elements) for the stripped, standard, and debug compilation cases are 134.7, 151.2, and 9.4, respectively. When scaling these errors with respect to the length of the ground truth arrays in the comparisons, the error ratios are 2.84, 5.44, and 0.11 for the compilation cases, respectively. This reveals that, in the debug case for example, the lengths of decompiler-inferred arrays are off by an average of 9.4 elements and roughly 11% (greater or less than) of the size of the ground truth arrays they are compared to. These metrics, however, fail to capture whether the decompiler-inferred array has element types of the correct length. Thus, a similar analysis on the size (number of bytes) errors yields errors and error ratios of 458.6 (0.91), 239 (0.47), and 9.41 (0.11) for each compilation case, respectively. This, for example, shows that arrays inferred in the standard compilation case have an average absolute byte differential of 239 and a relative error of 47% compared to the size of the ground truth array they are compared to.

In this analysis, we also capture a measure of the array dimension match score for each compilation case. This metric measures the fraction of array comparisons where the decompiler-inferred array has the same dimensionality (one-dimensional, two-dimensional, etc.) as the ground truth array. The stripped and standard compilation cases display dimensionality match ratios of greater than 97.4%, while the debug case shows 100% dimensionality inference accuracy.

The last portion of our array recovery analysis focuses on the element type inference accuracy of the decompiler-inferred arrays when compared to the element types of the ground truth arrays. We compute a data type comparison score between the element types from each array comparison and average these across all array comparisons derived from our benchmark programs. This data type comparison score is similar in concept to the varnode comparison score and is described in section XX. We find that decompiler-inferred arrays in the stripped, standard, and debug compilation cases show 0.781, 0.670, and

0.999 average element type comparison scores, respectively. The better performance demonstrated in the stripped case compared to the standard case appears to be a data artifact resulting from fewer array comparisons present in the stripped analysis.

### G. Debug Compilation Case Discussion

Upon examination of our results thus far, the reader may wonder why the debug compilation case does not produce 100% recovery for varnodes and data bytes across all benchmarks. The same DWARF debugging information used to generate the ground truth program information is also provided to the Ghidra decompiler in this case and therefore, theoretically, Ghidra should be able to precisely capture the same program information.

We manually investigate this phenomenon over our benchmark programs and find that the cause of these recovery inaccuracies stems from the Ghidra decompiler’s inflexibility in expressing local variables tied to lexical scopes. We find that the Ghidra decompiler output only lists variable declarations at the top level of the function and does not support declarations of local variables within lexical scopes. Instead, Ghidra attempts to move the declaration of these scope-specific variables to the top level of the function. Often, this behavior does not negatively influence the variable recovery of the given function. However, there are cases where multiple exclusive (not overlapping or nested) lexical scopes contain variable declarations. In many of these cases, the compiler recognizes the exclusivity of the lexical scopes and assigns the scope-specific variables to shared space on the stack since the variables shall never be instantiated simultaneously. The size of the shared region allocated by the decompiler is equivalent to the size of the largest variable in the set of scope-specific variables that share the region. In essence, this is equivalent to an implicit union formed by the compiler. The DWARF debugging standard and our DSL both possess the ability to express these overlapping scope-specific variables, but the Ghidra decompiler does not. From our observations, we find that Ghidra greedily captures and declares scope-specific variables at the top level of the function based on the order in which it recovers the variables. In the debug compilation case (utilizing DWARF information), Ghidra appears to only consider the first scope-specific variable mapped to a given address on the stack based on the order of the variables in the list of debugging information entries (DIEs) parsed from DWARF. The subsequent scope-specific variables associated with the given address are simply ignored, causing Ghidra to potentially miss several varnodes and data bytes. We consider this to be a shortcoming and an area of future improvement for the Ghidra decompiler.

## V. CONCLUSION

### A. Summary of Methodology

To develop our decompiler evaluation framework, we outline and execute the following objectives:

- 1) Express program information such as functions, variables, data types, and addresses in a common representation.
- 2) Programmatically capture a “ground truth” representation for a given program.
- 3) Programmatically scrape program information from decompiler tools, namely Ghidra.
- 4) Compare two program representations of the same program.
- 5) Formulate quantitative metrics for evaluating the accuracy of a decompiler.

We devise and implement a common domain-specific language (DSL) for expressing the association of high-level program information such as functions, variables, and data types, with binary-level constructs such as addresses and storage locations. With our DSL, we develop a parser for extracting DWARF debugging information from binary programs and representing this information in our DSL. This information is to be used as a ground truth source of program information in comparisons with decompiler representations. Next, we leverage the Ghidra Python API to develop a translator module, taking Ghidra decompilation output as our input and translating the information into our DSL. With our parsing modules constructed for both our ground truth and decompiler sources, we extend our DSL to support the comparison of two sources of program information parsed from a ground truth source and a decompiler source. We subsequently develop quantitative metrics for assessing and summarizing comparisons of program information sources.

### B. Summary of Results

We utilize our developed framework to assess the recovery performance of the Ghidra decompiler (version 10.2) over the 105 GNU Core Utilities (version 9.1) benchmark programs. Using the GCC compiler (version 11.1.0), we compile the benchmarks with no optimizations under three separate compilation configurations: (1) stripped, (2) standard (not stripped, no DWARF symbols added), (3) debug (DWARF symbols included).

Our function recovery analysis reveals that Ghidra recovers 100% of the 18139 functions across all benchmarks in the stripped and standard compilation cases. In the debug case, we find four missed functions in total, all present in the *factor* benchmark program. We discover that the missed functions are all caused by a decompiler error resulting from a failure in resolving a union data type. We conclude that this is a bug in the Ghidra decompiler.

In our high-level varnode analysis, we find that the recovery accuracy of primitive (*INT*, *FLOAT*, *POINTER*) metatypes is greater than that of the complex (aggregate) metatypes (*ARRAY*, *STRUCT*, *UNION*) across all compilation cases. This finding follows from the fact that inferring complex varnodes involves an extra layer of speculation and inference involving the synthesis of low-level varnodes. In all compilation cases, the *ARRAY* metatype displays the greatest number of “missed” varnodes.

Our decomposed (primitive) varnode analysis demonstrates that Ghidra is least effective at inferring floating-point (metatype *FLOAT*) decomposed varnodes over the benchmark programs in the stripped and standard compilation cases. However, we see that Ghidra completely misses a larger fraction of decomposed varnodes with metatype *INT*. This is explained by the larger incidence of integer arrays in the Coreutils benchmark programs, which are more likely to be missed or only partially recovered as demonstrated in our high-level varnode analysis. We show that decomposed varnodes of metatype *POINTER* are recovered comparably to those of metatype *INT*.

In our analysis of data bytes recovery summarized across all benchmarks, we find that the Ghidra decompiler shows 61.3% recovery in the stripped compilation case, 80.6% recovery in the standard case, and 99.5% recovery in the debug case.

Our array inference analysis illustrates that the compilation configuration of our benchmark programs has a significant impact on both array recovery and the inference accuracy of the arrays that are recovered. We find that, for each the stripped, standard, and debug compilation cases, 36.2%, 71.6%, and 99.5% of ground truth array varnodes overlap with at least one associated decompiler-inferred array varnode, respectively. We find the average size error ratio of the decompiler-inferred arrays with respect to the ground truth arrays to be 0.91, 0.47, and 0.11 for the compilation cases, respectively.

The function, variable, data bytes, and data type recovery analyses show clear recovery accuracy differentials between the three compilation cases. In general, we find that the debug case (DWARF symbols included) performs the best by a large margin, followed by the standard case which slightly outperforms the stripped case. Despite the decent recovery performance in the debug case, we seek an explanation for the decompiler still failing to capture a portion of the ground truth information, particularly varnodes and data bytes. We find that the Ghidra decompiler is limited in its ability to express overlapping stack variables gathered from non-overlapping, non-nested lexical scopes within the same parent function. This scenario arises when the compiler recognizes the exclusivity of lexical scopes within a function and subsequently assigns scope-specific variables from these lexical scopes to the same address or region on the stack.

### C. Limitations

The primary limitation of our framework in its current state is the lack of support for comparing and evaluating program information gathered from optimized binary programs. Our DSL supports the expression of program information from optimized binaries, but the comparison logic assumes certain properties about the program information to reduce the complexity of the analysis. Namely, we assume that each high-level variable to be associated with a single storage location in memory for the purposes of comparison. In addition, we assume that the program counter (PC) "live range" of the variable is the entire PC range of the parent function for local variables and the entire program for global variables.

In optimized binaries, these assumptions do not always hold. For example, optimizations may result in a single high-level variable being stored across a combination of stack locations and registers depending on the current instruction. In essence, optimizations introduce an additional temporal dimension that drastically increases the complexity of the analysis. Each live range of each variable would need to be considered, then a set of comparison "snapshots" would need to be performed based on the overlaps of the variable live ranges. An aggregation of these "snapshot" comparisons shall then be performed in such a way to evaluate the recovery of each of the high-level variables. Our current framework is built with this type of analysis in mind, but the scope of this work only considers the case of unoptimized binaries. Future work shall include the extension of the framework to support the evaluation of optimized binaries.

Another assumption in our analysis is that only non-parameter variables with stack and absolute (global) addresses are considered for comparison. This includes heap-allocated data which must be referenced by a pointer accessible from the current function. Our language and framework support the ability to represent register and register offset locations which shall be useful in future optimized analysis.

Another limitation in this work is our exclusive support for the DWARF debugging standard for extracting ground truth program information. However, as discussed previously, our framework can easily be extended to support the implementation of parsers for other debugging formats.

Regarding decompiler evaluation, our framework excels at assessing the recovery and inference of high-level program constructs. However, our framework lacks any form of behavioral analysis. Existing work by Liu and Wang [1] showcases an approach to evaluating the behavioral correctness of decompiler outputs. A full decompiler analysis shall combine our structural analysis with the behavioral analysis demonstrated by this existing work.

The final noteworthy limitation in our work is that we use our framework to assess only the Ghidra decompiler. We consider our framework to be the primary contribution of this research and therefore leave the analysis and comparison of other decompilers for future work.

### D. Future Work

As discussed in the previous section, a major future work objective shall be to extend our framework to support optimized binaries. In addition, we shall use our framework to assess and compare the recovery performance of decompilers beyond Ghidra.

In our function recovery analysis, recall that the Ghidra decompiler fails to decompile four functions within the *factor* program only in the case where DWARF debugging symbols are included. We conclude from the error messages returned that the decompilation errors for these functions result from Ghidra's inability to resolve a particular union data type present in the program. Since this error does not occur for the other compilation cases of the *factor* program, we gather

that the DWARF information scraped by Ghidra contributes to this error. With this observation, we recognize that a useful obfuscation strategy for binary programs may, instead of stripping all debugging symbols, be to include misleading and contradictory debugging information. Reverse engineering tools and decompilers analyzing a binary program with misleading debugging symbols included may produce incorrect outputs or potentially crash based on this erroneous information. This is certainly an area worthy of future research. In addition, the union resolution issue observed in our analysis shall be patched in the Ghidra framework.

In our assessment of the Ghidra decompiler, we observe that Ghidra does not successfully capture all ground truth variables and data bytes even in the case the DWARF debugging information is present. Upon further investigation, we discover this shortcoming is due to Ghidra's inability to express local variable declarations at the lexical scope level. Instead, Ghidra forces all local variables to be declared at the top level of the given function. This causes Ghidra to partially miss cases where the same stack address region is used by the compiler to store local variables declared in non-overlapping, non-nested lexical scopes within the same function. An area of future work shall be to modify the Ghidra decompiler to support the expression of more flexible local variable constructs that are not required to be declared at the top level of a function.

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## APPENDIX

TABLE VI: Function recovery (compilation = stripped)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
[	152	152	0	1.000
b2sum	148	148	0	1.000
base32	128	128	0	1.000
base64	129	129	0	1.000
basename	111	111	0	1.000
basenc	171	171	0	1.000
cat	124	124	0	1.000
chcon	247	247	0	1.000
chgrp	216	216	0	1.000
chmod	214	214	0	1.000
chown	218	218	0	1.000
chroot	125	125	0	1.000
cksum	246	246	0	1.000
comm	126	126	0	1.000
cp	335	335	0	1.000
csplit	339	339	0	1.000
cut	126	126	0	1.000
date	208	208	0	1.000
dd	197	197	0	1.000
df	266	266	0	1.000
dir	484	484	0	1.000
dircolors	125	125	0	1.000
dirname	108	108	0	1.000
du	513	513	0	1.000
echo	105	105	0	1.000
env	126	126	0	1.000
expand	121	121	0	1.000
expr	323	323	0	1.000
factor	174	174	0	1.000
false	104	104	0	1.000
fmt	131	131	0	1.000
fold	116	116	0	1.000
groups	112	112	0	1.000
head	135	135	0	1.000
hostid	106	106	0	1.000
id	142	142	0	1.000
join	152	152	0	1.000
kill	112	112	0	1.000
link	106	106	0	1.000
ln	231	231	0	1.000
logname	106	106	0	1.000
ls	484	484	0	1.000
md5sum	132	132	0	1.000
mkdir	165	165	0	1.000
mkfifo	131	131	0	1.000
mknod	134	134	0	1.000
mktemp	120	120	0	1.000
mv	394	394	0	1.000
nice	110	110	0	1.000
nl	307	307	0	1.000
nohup	115	115	0	1.000
nproc	113	113	0	1.000
numfmt	159	159	0	1.000
od	172	172	0	1.000
paste	114	114	0	1.000
pathchk	110	110	0	1.000
pinky	124	124	0	1.000
pr	208	208	0	1.000
printenv	105	105	0	1.000

Continued on

TABLE VI: Function recovery (compilation = stripped)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
printf	138	138	0	1.000
ptx	347	347	0	1.000
pwd	115	115	0	1.000
readlink	168	168	0	1.000
realpath	174	174	0	1.000
rm	234	234	0	1.000
rmdir	124	124	0	1.000
runcon	122	122	0	1.000
seq	129	129	0	1.000
sha1sum	133	133	0	1.000
sha224sum	140	140	0	1.000
sha256sum	140	140	0	1.000
sha384sum	140	140	0	1.000
sha512sum	140	140	0	1.000
shred	181	181	0	1.000
shuf	215	215	0	1.000
sleep	118	118	0	1.000
sort	349	349	0	1.000
split	154	154	0	1.000
stat	240	240	0	1.000
stdbuf	135	135	0	1.000
stty	149	149	0	1.000
sum	142	142	0	1.000
sync	108	108	0	1.000
tac	310	310	0	1.000
tail	234	234	0	1.000
tee	124	124	0	1.000
test	147	147	0	1.000
timeout	130	130	0	1.000
touch	198	198	0	1.000
tr	149	149	0	1.000
true	104	104	0	1.000
truncate	114	114	0	1.000
tsort	125	125	0	1.000
tty	105	105	0	1.000
uname	107	107	0	1.000
unexpand	121	121	0	1.000
uniq	132	132	0	1.000
unlink	106	106	0	1.000
uptime	142	142	0	1.000
users	112	112	0	1.000
vdir	484	484	0	1.000
wc	152	152	0	1.000
who	138	138	0	1.000
whoami	106	106	0	1.000
yes	109	109	0	1.000

TABLE VII: Function recovery (compilation = standard)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
[	152	152	0	1.000
b2sum	148	148	0	1.000
base32	128	128	0	1.000
base64	129	129	0	1.000
basename	111	111	0	1.000
basenc	171	171	0	1.000
cat	124	124	0	1.000
chcon	247	247	0	1.000
chgrp	216	216	0	1.000

Continued on



TABLE VII: Function recovery (compilation = standard)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
chmod	214	214	0	1.000
chown	218	218	0	1.000
chroot	125	125	0	1.000
cksum	246	246	0	1.000
comm	126	126	0	1.000
cp	335	335	0	1.000
csplit	339	339	0	1.000
cut	126	126	0	1.000
date	208	208	0	1.000
dd	197	197	0	1.000
df	266	266	0	1.000
dir	484	484	0	1.000
dircolors	125	125	0	1.000
dirname	108	108	0	1.000
du	513	513	0	1.000
echo	105	105	0	1.000
env	126	126	0	1.000
expand	121	121	0	1.000
expr	323	323	0	1.000
factor	174	174	0	1.000
false	104	104	0	1.000
fmt	131	131	0	1.000
fold	116	116	0	1.000
groups	112	112	0	1.000
head	135	135	0	1.000
hostid	106	106	0	1.000
id	142	142	0	1.000
join	152	152	0	1.000
kill	112	112	0	1.000
link	106	106	0	1.000
ln	231	231	0	1.000
logname	106	106	0	1.000
ls	484	484	0	1.000
md5sum	132	132	0	1.000
mkdir	165	165	0	1.000
mkfifo	131	131	0	1.000
mknod	134	134	0	1.000
mktemp	120	120	0	1.000
mv	394	394	0	1.000
nice	110	110	0	1.000
nl	307	307	0	1.000
nohup	115	115	0	1.000
nproc	113	113	0	1.000
numfmt	159	159	0	1.000
od	172	172	0	1.000
paste	114	114	0	1.000
pathchk	110	110	0	1.000
pinky	124	124	0	1.000
pr	208	208	0	1.000
printenv	105	105	0	1.000
printf	138	138	0	1.000
ptx	347	347	0	1.000
pwd	115	115	0	1.000
readlink	168	168	0	1.000
realpath	174	174	0	1.000
rm	234	234	0	1.000
rmdir	124	124	0	1.000
runcon	122	122	0	1.000
seq	129	129	0	1.000
sha1sum	133	133	0	1.000
sha224sum	140	140	0	1.000

Continued on

TABLE VII: Function recovery (compilation = standard)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
sha256sum	140	140	0	1.000
sha384sum	140	140	0	1.000
sha512sum	140	140	0	1.000
shred	181	181	0	1.000
shuf	215	215	0	1.000
sleep	118	118	0	1.000
sort	349	349	0	1.000
split	154	154	0	1.000
stat	240	240	0	1.000
stdbuf	135	135	0	1.000
stty	149	149	0	1.000
sum	142	142	0	1.000
sync	108	108	0	1.000
tac	310	310	0	1.000
tail	234	234	0	1.000
tee	124	124	0	1.000
test	147	147	0	1.000
timeout	130	130	0	1.000
touch	198	198	0	1.000
tr	149	149	0	1.000
true	104	104	0	1.000
truncate	114	114	0	1.000
tsort	125	125	0	1.000
tty	105	105	0	1.000
uname	107	107	0	1.000
unexpand	121	121	0	1.000
uniq	132	132	0	1.000
unlink	106	106	0	1.000
uptime	142	142	0	1.000
users	112	112	0	1.000
vdir	484	484	0	1.000
wc	152	152	0	1.000
who	138	138	0	1.000
whoami	106	106	0	1.000
yes	109	109	0	1.000

TABLE VIII: Function recovery (compilation = debug)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
[	152	152	0	1.000
b2sum	148	148	0	1.000
base32	128	128	0	1.000
base64	129	129	0	1.000
basename	111	111	0	1.000
basenc	171	171	0	1.000
cat	124	124	0	1.000
chcon	247	247	0	1.000
chgrp	216	216	0	1.000
chmod	214	214	0	1.000
chown	218	218	0	1.000
chroot	125	125	0	1.000
cksum	246	246	0	1.000
comm	126	126	0	1.000
cp	335	335	0	1.000
csplit	339	339	0	1.000
cut	126	126	0	1.000
date	208	208	0	1.000
dd	197	197	0	1.000
df	266	266	0	1.000

Continued on

TABLE VIII: Function recovery (compilation = debug)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
dir	484	484	0	1.000
dircolors	125	125	0	1.000
dirname	108	108	0	1.000
du	513	513	0	1.000
echo	105	105	0	1.000
env	126	126	0	1.000
expand	121	121	0	1.000
expr	323	323	0	1.000
factor	174	170	4	0.977
false	104	104	0	1.000
fmt	131	131	0	1.000
fold	116	116	0	1.000
groups	112	112	0	1.000
head	135	135	0	1.000
hostid	106	106	0	1.000
id	142	142	0	1.000
join	152	152	0	1.000
kill	112	112	0	1.000
link	106	106	0	1.000
ln	231	231	0	1.000
logname	106	106	0	1.000
ls	484	484	0	1.000
md5sum	132	132	0	1.000
mkdir	165	165	0	1.000
mkfifo	131	131	0	1.000
mknod	134	134	0	1.000
mktemp	120	120	0	1.000
mv	394	394	0	1.000
nice	110	110	0	1.000
nl	307	307	0	1.000
nohup	115	115	0	1.000
nproc	113	113	0	1.000
numfmt	159	159	0	1.000
od	172	172	0	1.000
paste	114	114	0	1.000
pathchk	110	110	0	1.000
pinky	124	124	0	1.000
pr	208	208	0	1.000
printenv	105	105	0	1.000
printf	138	138	0	1.000
ptx	347	347	0	1.000
pwd	115	115	0	1.000
readlink	168	168	0	1.000
realpath	174	174	0	1.000
rm	234	234	0	1.000
rmdir	124	124	0	1.000
runcon	122	122	0	1.000
seq	129	129	0	1.000
sha1sum	133	133	0	1.000
sha224sum	140	140	0	1.000
sha256sum	140	140	0	1.000
sha384sum	140	140	0	1.000
sha512sum	140	140	0	1.000
shred	181	181	0	1.000
shuf	215	215	0	1.000
sleep	118	118	0	1.000
sort	349	349	0	1.000
split	154	154	0	1.000
stat	240	240	0	1.000
stdbuf	135	135	0	1.000
stty	149	149	0	1.000

Continued on

TABLE VIII: Function recovery (compilation = debug)

	Ground truth functions	Functions found	Functions missed	Functions recovery frac
sum	142	142	0	1.000
sync	108	108	0	1.000
tac	310	310	0	1.000
tail	234	234	0	1.000
tee	124	124	0	1.000
test	147	147	0	1.000
timeout	130	130	0	1.000
touch	198	198	0	1.000
tr	149	149	0	1.000
true	104	104	0	1.000
truncate	114	114	0	1.000
tsort	125	125	0	1.000
tty	105	105	0	1.000
uname	107	107	0	1.000
unexpand	121	121	0	1.000
uniq	132	132	0	1.000
unlink	106	106	0	1.000
uptime	142	142	0	1.000
users	112	112	0	1.000
vdir	484	484	0	1.000
wc	152	152	0	1.000
who	138	138	0	1.000
whoami	106	106	0	1.000
yes	109	109	0	1.000

TABLE IX: Varnode recovery (compilation = stripped)

	Ground truth varnodes	truth Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode frac- tion partially recovered
[	266	5	20	10	125	106	0.789	0.981
b2sum	237	8	9	9	115	96	0.797	0.966
base32	160	7	7	4	79	63	0.787	0.956
base64	160	7	7	4	79	63	0.787	0.956
basename	129	5	7	4	74	39	0.762	0.961
basenc	219	14	9	4	103	89	0.779	0.936
cat	164	5	8	5	92	54	0.777	0.970
chcon	363	8	16	7	229	103	0.778	0.978
chgrp	339	8	15	9	200	107	0.782	0.976
chmod	347	9	16	11	206	105	0.775	0.974
chown	359	8	16	9	206	120	0.788	0.978
chroot	198	5	9	4	84	96	0.824	0.975
cksum	678	31	26	20	392	209	0.766	0.954
comm	171	5	13	5	99	49	0.754	0.971
cp	703	17	32	30	351	273	0.796	0.976
csplit	982	15	43	17	533	374	0.808	0.985
cut	192	7	8	4	112	61	0.776	0.964
date	747	29	40	37	383	258	0.768	0.961
dd	493	18	20	12	243	200	0.798	0.963
df	640	9	25	15	283	308	0.834	0.986
dir	1031	30	56	28	544	373	0.785	0.971
dircolors	190	6	8	6	111	59	0.775	0.968
dirname	125	6	7	4	70	38	0.754	0.952
du	1499	30	56	34	824	555	0.803	0.980
echo	118	4	7	4	68	35	0.761	0.966
env	201	9	12	5	97	78	0.777	0.955
expand	152	6	8	5	87	46	0.762	0.961
expr	911	15	38	27	489	342	0.803	0.984

TABLE IX: Varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode frac- tion partial recovery
factor	511		31	27	24	187	242	0.785	0.939
false	109		4	7	4	63	31	0.752	0.963
fmt	186		6	8	4	107	61	0.781	0.968
fold	143		6	8	4	75	50	0.771	0.958
groups	142		6	7	4	77	48	0.771	0.958
head	215		5	15	6	113	76	0.779	0.977
hostid	118		5	7	6	69	31	0.742	0.958
id	196		8	8	4	99	77	0.792	0.959
join	260		9	12	5	145	89	0.782	0.965
kill	148		7	9	4	76	52	0.765	0.953
link	117		5	7	6	68	31	0.741	0.957
ln	433		8	17	16	230	162	0.801	0.982
logname	118		5	7	6	69	31	0.742	0.958
ls	1031		30	56	28	544	373	0.785	0.971
md5sum	217		7	13	4	117	76	0.779	0.968
mkdir	306		7	15	10	146	128	0.805	0.977
mkfifo	148		6	9	5	83	45	0.757	0.959
mknod	165		6	9	5	86	59	0.777	0.964
mktemp	164		6	8	5	91	54	0.773	0.963
mv	773		15	37	26	427	268	0.790	0.981
nice	130		5	7	4	70	44	0.771	0.962
nl	896		23	39	17	468	349	0.802	0.974
nohup	162		5	8	6	102	41	0.756	0.969
nproc	139		5	7	4	74	49	0.779	0.964
numfmt	291		9	13	9	139	121	0.801	0.969
od	459		11	27	12	205	204	0.807	0.976
paste	142		5	7	4	82	44	0.769	0.965
pathchk	141		6	8	4	84	39	0.752	0.957
pinky	182		8	12	5	106	51	0.747	0.956
pr	543		12	18	10	324	179	0.795	0.978
printenv	119		5	7	4	65	38	0.761	0.958
printf	283		6	18	8	133	118	0.799	0.979
ptx	1126		19	56	32	575	444	0.804	0.983
pwd	143		5	8	9	84	37	0.745	0.965
readlink	243		6	10	7	134	86	0.792	0.975
realpath	248		6	10	7	135	90	0.795	0.976
rm	362		9	15	9	218	111	0.781	0.975
rmdir	234		6	10	7	112	99	0.808	0.974
runcon	121		5	7	4	72	33	0.750	0.959
seq	279		8	21	8	121	121	0.792	0.971
sha1sum	215		7	10	5	113	80	0.790	0.967
sha224sum	225		8	13	5	116	83	0.781	0.964
sha256sum	225		8	13	5	116	83	0.781	0.964
sha384sum	381		8	8	5	275	85	0.776	0.979
sha512sum	381		8	8	5	275	85	0.776	0.979
shred	370		9	21	8	200	132	0.787	0.976
shuf	374		6	9	6	215	138	0.814	0.984
sleep	143		5	9	6	77	46	0.762	0.965
sort	847		22	38	18	460	309	0.794	0.974
split	297		9	14	5	153	116	0.797	0.970
stat	608		20	22	20	313	233	0.795	0.967
stdbuf	267		7	10	9	125	116	0.812	0.974
stty	301		8	16	10	132	135	0.807	0.973
sum	278		8	13	7	136	114	0.801	0.971
sync	133		5	8	4	78	38	0.756	0.962
tac	920		17	39	18	500	346	0.804	0.982
tail	423		7	25	11	215	165	0.799	0.983
tee	154		6	9	5	90	44	0.755	0.961

TABLE IX: Varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode fraction partially recovered
test	260		4	19	9	125	103	0.792	0.985
timeout	175		6	10	4	86	69	0.789	0.966
touch	602		25	37	36	298	206	0.759	0.958
tr	241		9	9	6	114	103	0.804	0.963
true	109		4	7	4	63	31	0.752	0.963
truncate	145		5	8	5	80	47	0.769	0.966
tsort	162		5	10	6	93	48	0.761	0.969
tty	114		5	7	4	66	32	0.748	0.956
uname	120		6	7	5	68	34	0.744	0.950
unexpand	158		5	7	5	89	52	0.778	0.968
uniq	202		7	10	6	112	67	0.775	0.965
unlink	117		5	7	6	68	31	0.741	0.957
uptime	353		11	12	12	210	108	0.778	0.969
users	133		5	7	6	78	37	0.754	0.962
vdir	1031		30	56	28	544	373	0.785	0.971
wc	268		8	8	8	148	96	0.795	0.970
who	282		10	10	8	138	116	0.801	0.965
whoami	120		5	7	6	71	31	0.742	0.958
yes	132		5	7	6	77	37	0.754	0.962

TABLE X: Varnode recovery (metatype = INT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	157		0	0	0	83	74	0.868	1.000
b2sum	147		0	0	0	80	67	0.864	1.000
base32	96		0	0	0	51	45	0.867	1.000
base64	96		0	0	0	51	45	0.867	1.000
basename	71		0	0	0	47	24	0.835	1.000
basenc	133		0	1	0	70	62	0.863	1.000
cat	101		0	0	0	64	37	0.842	1.000
chcon	185		0	0	0	124	61	0.832	1.000
chgrp	166		0	0	0	103	63	0.845	1.000
chmod	176		0	0	0	110	66	0.844	1.000
chown	176		0	0	0	105	71	0.851	1.000
chroot	110		0	1	0	53	56	0.873	1.000
cksum	488		2	0	0	329	157	0.827	0.996
comm	104		0	0	0	74	30	0.822	1.000
cp	382		2	1	0	206	173	0.858	0.995
csplit	619		0	1	0	325	293	0.868	1.000
cut	124		1	0	0	80	43	0.831	0.992
date	516		4	10	0	317	185	0.824	0.992
dd	332		1	0	0	186	145	0.857	0.997
df	326		0	0	0	158	168	0.879	1.000
dir	615		4	3	0	364	244	0.842	0.993
dircolors	90		0	0	0	58	32	0.839	1.000
dirname	73		1	0	0	46	26	0.829	0.986
du	931		4	3	0	518	406	0.854	0.996
echo	69		0	0	0	45	24	0.837	1.000
env	112		0	0	0	61	51	0.864	1.000
expand	94		0	0	0	59	35	0.843	1.000
expr	560		0	1	0	286	273	0.871	1.000
factor	343		21	2	0	128	192	0.841	0.939

TABLE X: Varnode recovery (metatype = INT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
false	62		0	0	0	40	22	0.839	1.000
fmt	112		0	0	0	72	40	0.839	1.000
fold	88		0	0	0	51	37	0.855	1.000
groups	81		0	0	0	51	30	0.843	1.000
head	138		0	0	0	82	56	0.851	1.000
hostid	67		0	0	0	45	22	0.832	1.000
id	112		0	0	0	69	43	0.846	1.000
join	162		0	0	0	104	58	0.840	1.000
kill	88		0	0	0	52	36	0.852	1.000
link	66		0	0	0	44	22	0.833	1.000
ln	219		0	0	0	125	94	0.857	1.000
logname	66		0	0	0	44	22	0.833	1.000
ls	615		4	3	0	364	244	0.842	0.993
md5sum	139		0	0	0	81	58	0.854	1.000
mkdir	196		0	0	0	102	94	0.870	1.000
mkfifo	88		0	0	0	53	35	0.849	1.000
mknod	100		0	0	0	54	46	0.865	1.000
mktemp	96		0	0	0	60	36	0.844	1.000
mv	428		2	0	0	238	188	0.856	0.995
nice	77		0	0	0	47	30	0.847	1.000
nl	558		0	1	0	288	269	0.870	1.000
nohup	99		0	0	0	71	28	0.821	1.000
nproc	86		0	0	0	51	35	0.852	1.000
numfmt	184		0	0	0	98	86	0.867	1.000
od	294		0	1	0	146	147	0.873	1.000
paste	85		0	0	0	55	30	0.838	1.000
pathchk	85		0	0	0	57	28	0.832	1.000
pinky	96		0	0	0	65	31	0.831	1.000
pr	399		4	1	0	258	136	0.826	0.990
printenv	68		0	0	0	42	26	0.846	1.000
printf	168		0	2	0	85	81	0.865	1.000
ptx	673		0	1	0	347	325	0.870	1.000
pwd	75		0	0	0	50	25	0.833	1.000
readlink	111		0	0	0	69	42	0.845	1.000
realpath	111		0	0	0	65	46	0.854	1.000
rm	185		0	0	0	115	70	0.845	1.000
rmdir	139		0	0	0	73	66	0.869	1.000
runcon	65		0	0	0	42	23	0.838	1.000
seq	156		0	0	0	78	78	0.875	1.000
sha1sum	138		0	0	0	78	60	0.859	1.000
sha224sum	145		0	0	0	80	65	0.862	1.000
sha256sum	145		0	0	0	80	65	0.862	1.000
sha384sum	301		0	0	0	236	65	0.804	1.000
sha512sum	301		0	0	0	236	65	0.804	1.000
shred	238		0	0	0	140	98	0.853	1.000
shuf	210		0	0	0	129	81	0.846	1.000
sleep	76		0	0	0	49	27	0.839	1.000
sort	440		0	0	0	260	180	0.852	1.000
split	195		0	0	0	109	86	0.860	1.000
stat	392		4	1	0	233	154	0.839	0.990
stdbuf	156		0	0	0	80	76	0.872	1.000
stty	189		0	1	0	89	99	0.878	1.000
sum	183		0	0	0	99	84	0.865	1.000
sync	83		0	0	0	54	29	0.837	1.000
tac	584		0	1	0	310	273	0.866	1.000
tail	239		0	0	0	141	98	0.853	1.000
tee	95		0	0	0	62	33	0.837	1.000

TABLE X: Varnode recovery (metatype = INT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
test	155		0	0	0	83	72	0.866	1.000
timeout	95		0	0	0	55	40	0.855	1.000
touch	396		4	9	0	240	143	0.821	0.990
tr	153		0	0	0	70	83	0.886	1.000
true	62		0	0	0	40	22	0.839	1.000
truncate	91		0	0	0	55	36	0.849	1.000
tsort	85		0	0	0	55	30	0.838	1.000
tty	65		0	0	0	43	22	0.835	1.000
uname	67		0	0	0	43	24	0.840	1.000
unexpand	101		0	0	0	61	40	0.849	1.000
uniq	125		0	0	0	79	46	0.842	1.000
unlink	66		0	0	0	44	22	0.833	1.000
uptime	261		4	1	0	170	86	0.819	0.985
users	73		0	0	0	47	26	0.839	1.000
vdir	615		4	3	0	364	244	0.842	0.993
wc	148		0	0	0	90	58	0.848	1.000
who	158		0	0	0	90	68	0.858	1.000
whoami	68		0	0	0	46	22	0.831	1.000
yes	76		0	0	0	50	26	0.836	1.000

TABLE XI: Varnode recovery (metatype = FLOAT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	2		0	1	0	1	0	0.500	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	3		0	0	0	3	0	0.750	1.000
chgrp	3		0	0	0	3	0	0.750	1.000
chmod	3		0	0	0	3	0	0.750	1.000
chown	3		0	0	0	3	0	0.750	1.000
chroot	0		0	0	0	0	0	-	-
cksum	3		0	2	0	1	0	0.417	1.000
comm	0		0	0	0	0	0	-	-
cp	3		0	0	0	3	0	0.750	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	1	0	1	0	0.500	1.000
dd	7		0	3	0	4	0	0.536	1.000
df	13		0	3	0	5	5	0.731	1.000
dir	6		0	2	0	4	0	0.583	1.000
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	6		0	2	0	4	0	0.583	1.000
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-



TABLE XI: Varnode recovery (metatype = FLOAT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	3		0	0	0	3	0	0.750	1.000
logname	0		0	0	0	0	0	-	-
ls	6		0	2	0	4	0	0.583	1.000
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	1	0	1	0	0.500	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	3		0	0	0	3	0	0.750	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	5	0	2	0	0.393	1.000
od	11		0	3	0	8	0	0.614	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	5	0	2	0	0.393	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	3		0	0	0	3	0	0.750	1.000
realpath	3		0	0	0	3	0	0.750	1.000
rm	3		0	0	0	3	0	0.750	1.000
rmdir	2		0	1	0	1	0	0.500	1.000
runcon	0		0	0	0	0	0	-	-
seq	10		0	9	0	1	0	0.300	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	2	0	1	0	0.417	1.000
shuf	3		0	0	0	3	0	0.750	1.000
sleep	7		0	0	0	2	5	0.929	1.000
sort	18		0	4	0	12	2	0.667	1.000
split	0		0	0	0	0	0	-	-
stat	2		0	1	0	1	0	0.500	1.000
stdbuf	2		0	1	0	1	0	0.500	1.000
stty	2		0	1	0	1	0	0.500	1.000
sum	3		0	2	0	1	0	0.417	1.000
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	11		0	0	0	6	5	0.864	1.000

TABLE XI: Varnode recovery (metatype = FLOAT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
tee	0		0	0	0	0	0	-	-
test	2		0	1	0	1	0	0.500	1.000
timeout	8		0	0	0	4	4	0.875	1.000
touch	2		0	1	0	1	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	2		0	0	0	1	1	0.875	1.000
users	0		0	0	0	0	0	-	-
vdir	6		0	2	0	4	0	0.583	1.000
wc	4		0	0	0	4	0	0.750	1.000
who	2		0	1	0	1	0	0.500	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XII: Varnode recovery (metatype = POINTER) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	68		0	0	0	38	30	0.860	1.000
b2sum	56		0	0	0	32	24	0.857	1.000
base32	41		0	0	0	24	17	0.854	1.000
base64	41		0	0	0	24	17	0.854	1.000
basename	38		0	0	0	24	14	0.842	1.000
basenc	55		0	0	0	30	25	0.864	1.000
cat	41		0	0	0	25	16	0.848	1.000
chcon	134		1	0	0	93	40	0.819	0.993
chgrp	133		1	0	0	90	42	0.823	0.992
chmod	127		1	0	0	89	37	0.817	0.992
chown	142		1	0	0	94	47	0.827	0.993
chroot	67		0	0	0	28	39	0.896	1.000
cksum	99		0	0	0	56	43	0.859	1.000
comm	35		0	0	0	22	13	0.843	1.000
cp	231		0	0	0	133	98	0.856	1.000
csplit	272		6	0	0	202	64	0.792	0.978
cut	46		0	0	0	29	17	0.842	1.000
date	125		1	0	0	60	64	0.872	0.992
dd	98		0	0	0	50	48	0.872	1.000
df	239		0	0	0	110	129	0.885	1.000
dir	293		1	0	0	171	121	0.851	0.997
dircolors	76		0	0	0	50	26	0.836	1.000
dirname	32		0	0	0	21	11	0.836	1.000
du	438		8	0	0	295	135	0.813	0.982
echo	30		0	0	0	20	10	0.833	1.000
env	54		0	0	0	32	22	0.852	1.000
expand	35		0	0	0	25	10	0.821	1.000

TABLE XII: Varnode recovery (metatype = POINTER) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
expr	259		6	0	0	197	56	0.787	0.977
factor	98		1	0	0	57	40	0.844	0.990
false	28		0	0	0	20	8	0.821	1.000
fmt	52		0	0	0	32	20	0.846	1.000
fold	33		0	0	0	21	12	0.841	1.000
groups	40		0	0	0	23	17	0.856	1.000
head	47		0	0	0	28	19	0.851	1.000
hostid	29		0	0	0	21	8	0.819	1.000
id	60		0	0	0	27	33	0.887	1.000
join	66		0	0	0	38	28	0.856	1.000
kill	36		0	0	0	21	15	0.854	1.000
link	29		0	0	0	21	8	0.819	1.000
ln	161		0	0	0	95	66	0.852	1.000
logname	30		0	0	0	22	8	0.817	1.000
ls	293		1	0	0	171	121	0.851	0.997
md5sum	50		0	0	0	33	17	0.835	1.000
mkdir	71		0	0	0	39	32	0.863	1.000
mkfifo	36		0	0	0	27	9	0.812	1.000
mknod	41		0	0	0	29	12	0.823	1.000
mktemp	44		0	0	0	28	16	0.841	1.000
mv	254		1	0	0	176	77	0.823	0.996
nice	33		0	0	0	20	13	0.848	1.000
nl	247		6	0	0	174	67	0.800	0.976
nohup	40		0	0	0	28	12	0.825	1.000
nproc	32		0	0	0	20	12	0.844	1.000
numfmt	70		0	0	0	36	34	0.871	1.000
od	93		0	0	0	40	53	0.892	1.000
paste	37		0	0	0	24	13	0.838	1.000
pathchk	33		0	0	0	23	10	0.826	1.000
pinky	57		0	0	0	38	19	0.833	1.000
pr	102		1	0	0	62	39	0.838	0.990
printenv	31		0	0	0	20	11	0.839	1.000
printf	76		0	2	0	40	34	0.849	1.000
ptx	331		6	0	0	219	106	0.816	0.982
pwd	41		0	0	0	30	11	0.817	1.000
readlink	100		0	0	0	57	43	0.858	1.000
realpath	105		0	0	0	62	43	0.852	1.000
rm	136		1	0	0	96	39	0.816	0.993
rmdir	66		0	0	0	35	31	0.867	1.000
runcon	36		0	0	0	27	9	0.812	1.000
seq	81		0	1	0	39	41	0.870	1.000
sha1sum	49		0	0	0	32	17	0.837	1.000
sha224sum	50		0	0	0	33	17	0.835	1.000
sha256sum	50		0	0	0	33	17	0.835	1.000
sha384sum	50		0	0	0	33	17	0.835	1.000
sha512sum	50		0	0	0	33	17	0.835	1.000
shred	87		0	0	0	56	31	0.839	1.000
shuf	134		0	0	0	79	55	0.853	1.000
sleep	35		0	0	0	23	12	0.836	1.000
sort	299		0	0	0	182	117	0.848	1.000
split	69		0	0	0	41	28	0.851	1.000
stat	150		1	0	0	73	76	0.872	0.993
stdbuf	79		0	0	0	41	38	0.870	1.000
stty	73		0	0	0	39	34	0.866	1.000
sum	60		0	0	0	33	27	0.863	1.000
sync	29		0	0	0	21	8	0.819	1.000
tac	250		6	0	0	184	60	0.792	0.976

TABLE XII: Varnode recovery (metatype = POINTER) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
tail	124		0	1	0	65	58	0.863	1.000
tee	35		0	0	0	25	10	0.821	1.000
test	67		0	0	0	38	29	0.858	1.000
timeout	41		0	0	0	23	18	0.860	1.000
touch	110		1	0	0	53	56	0.870	0.991
tr	58		0	0	0	39	19	0.832	1.000
true	28		0	0	0	20	8	0.821	1.000
truncate	32		0	0	0	22	10	0.828	1.000
tsort	52		0	0	0	35	17	0.832	1.000
tty	29		0	0	0	20	9	0.828	1.000
uname	30		0	0	0	22	8	0.817	1.000
unexpand	36		0	0	0	25	11	0.826	1.000
uniq	50		0	0	0	30	20	0.850	1.000
unlink	29		0	0	0	21	8	0.819	1.000
uptime	57		1	0	0	36	20	0.825	0.982
users	38		0	0	0	28	10	0.816	1.000
vdir	293		1	0	0	171	121	0.851	0.997
wc	84		0	0	0	52	32	0.845	1.000
who	83		0	0	0	44	39	0.867	1.000
whoami	30		0	0	0	22	8	0.817	1.000
yes	34		0	0	0	24	10	0.824	1.000

TABLE XIII: Varnode recovery (metatype = ARRAY) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	15		4	5	4	0	2	0.350	0.733
b2sum	24		7	4	8	0	5	0.417	0.708
base32	12		6	2	3	0	1	0.250	0.500
base64	12		6	2	3	0	1	0.250	0.500
basename	10		4	2	3	0	1	0.300	0.600
basenc	20		13	2	3	0	2	0.200	0.350
cat	11		4	3	3	0	1	0.295	0.636
chcon	18		4	10	3	0	1	0.278	0.778
chgrp	15		4	7	3	0	1	0.283	0.733
chmod	19		5	8	5	0	1	0.289	0.737
chown	16		4	8	3	0	1	0.281	0.750
chroot	11		4	3	3	0	1	0.295	0.636
cksum	66		28	10	19	0	9	0.318	0.576
comm	22		4	8	4	0	6	0.455	0.818
cp	40		12	13	11	3	1	0.300	0.700
csplit	35		8	13	6	0	8	0.407	0.771
cut	12		5	3	3	0	1	0.271	0.583
date	63		23	14	20	0	6	0.310	0.635
dd	34		16	7	8	0	3	0.257	0.529
df	25		7	9	6	1	2	0.320	0.720
dir	71		21	27	19	1	3	0.282	0.704
dircolors	13		5	2	5	0	1	0.308	0.615
dirname	10		4	2	3	0	1	0.300	0.600
du	51		15	16	12	0	8	0.353	0.706
echo	9		3	2	3	0	1	0.333	0.667
env	18		6	7	3	1	1	0.278	0.667

TABLE XIII: Varnode recovery (metatype = ARRAY) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
expand	13		5	3	4	0	1	0.288	0.615
expr	33		8	9	8	0	8	0.432	0.758
factor	37		8	10	10	0	9	0.446	0.784
false	9		3	2	3	0	1	0.333	0.667
fmt	12		5	3	3	0	1	0.271	0.583
fold	12		5	3	3	0	1	0.271	0.583
groups	11		5	2	3	0	1	0.273	0.545
head	18		4	9	4	0	1	0.292	0.778
hostid	12		4	2	5	0	1	0.333	0.667
id	14		7	3	3	0	1	0.232	0.500
join	18		7	5	3	0	3	0.319	0.611
kill	14		6	4	3	0	1	0.250	0.571
link	12		4	2	5	0	1	0.333	0.667
ln	22		6	7	5	3	1	0.341	0.727
logname	12		4	2	5	0	1	0.333	0.667
ls	71		21	27	19	1	3	0.282	0.704
md5sum	16		6	6	3	0	1	0.250	0.625
mkdir	19		6	7	4	0	2	0.303	0.684
mkfifo	12		5	3	3	0	1	0.271	0.583
mknod	12		5	3	3	0	1	0.271	0.583
mktemp	12		5	2	4	0	1	0.292	0.583
mv	34		9	14	7	3	1	0.301	0.735
nice	10		4	2	3	0	1	0.300	0.600
nl	36		13	9	6	0	8	0.368	0.639
nohup	13		4	3	5	0	1	0.327	0.692
nproc	10		4	2	3	0	1	0.300	0.600
numfmt	20		8	3	8	0	1	0.287	0.600
od	40		10	18	8	0	4	0.312	0.750
paste	10		4	2	3	0	1	0.300	0.600
pathchk	10		4	2	3	0	1	0.300	0.600
pinky	17		6	7	3	0	1	0.250	0.647
pr	20		6	6	6	0	2	0.325	0.700
printenv	10		4	2	3	0	1	0.300	0.600
printf	17		5	4	5	0	3	0.382	0.706
ptx	39		12	9	7	3	8	0.410	0.692
pwd	10		4	2	3	0	1	0.300	0.600
readlink	12		4	3	3	1	1	0.333	0.667
realpath	11		4	2	3	1	1	0.341	0.636
rm	15		5	5	4	0	1	0.283	0.667
rmdir	14		5	3	4	0	2	0.339	0.643
runcon	10		4	2	3	0	1	0.300	0.600
seq	15		7	2	4	0	2	0.300	0.533
sha1sum	16		6	3	4	0	3	0.359	0.625
sha224sum	17		7	5	4	0	1	0.250	0.588
sha256sum	17		7	5	4	0	1	0.250	0.588
sha384sum	17		7	3	4	0	3	0.338	0.588
sha512sum	17		7	3	4	0	3	0.338	0.588
shred	27		8	11	5	0	3	0.306	0.704
shuf	12		4	3	3	0	2	0.354	0.667
sleep	12		4	2	5	0	1	0.333	0.667
sort	46		19	17	8	0	2	0.223	0.587
split	18		6	7	4	0	1	0.264	0.667
stat	32		14	7	9	0	2	0.258	0.562
stdbuf	16		6	3	5	0	2	0.328	0.625
stty	19		5	5	7	0	2	0.355	0.737
sum	22		7	6	6	0	3	0.341	0.682
sync	11		4	3	3	0	1	0.295	0.636

TABLE XIII: Varnode recovery (metatype = ARRAY) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
tac	33		9	9	7	0	8	0.417	0.727
tail	20		5	9	5	0	1	0.287	0.750
tee	14		5	4	4	0	1	0.286	0.643
test	12		3	4	3	0	2	0.375	0.750
timeout	13		5	4	3	0	1	0.269	0.615
touch	56		19	14	17	0	6	0.321	0.661
tr	17		8	3	5	0	1	0.250	0.529
true	9		3	2	3	0	1	0.333	0.667
truncate	10		4	2	3	0	1	0.300	0.600
tsort	13		4	3	5	0	1	0.327	0.692
tty	10		4	2	3	0	1	0.300	0.600
uname	12		5	2	4	0	1	0.292	0.583
unexpand	11		4	2	4	0	1	0.318	0.636
uniq	15		6	3	5	0	1	0.283	0.600
unlink	12		4	2	5	0	1	0.333	0.667
uptime	18		5	4	8	0	1	0.333	0.722
users	12		4	2	5	0	1	0.333	0.667
vdir	71		21	27	19	1	3	0.282	0.704
wc	16		7	3	5	0	1	0.266	0.562
who	25		8	4	4	0	9	0.480	0.680
whoami	12		4	2	5	0	1	0.333	0.667
yes	12		4	2	5	0	1	0.333	0.667

TABLE XIV: Varnode recovery (metatype = STRUCT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	24		1	14	6	3	0	0.365	0.958
b2sum	10		1	5	1	3	0	0.400	0.900
base32	11		1	5	1	4	0	0.432	0.909
base64	11		1	5	1	4	0	0.432	0.909
basename	10		1	5	1	3	0	0.400	0.900
basenc	11		1	6	1	3	0	0.386	0.909
cat	11		1	5	2	3	0	0.409	0.909
chcon	23		3	6	4	9	1	0.489	0.870
chgrp	22		3	8	6	4	1	0.409	0.864
chmod	22		3	8	6	4	1	0.409	0.864
chown	22		3	8	6	4	1	0.409	0.864
chroot	10		1	5	1	3	0	0.400	0.900
cksum	22		1	14	1	6	0	0.386	0.955
comm	10		1	5	1	3	0	0.400	0.900
cp	46		3	18	19	5	1	0.408	0.935
csplit	56		1	29	11	6	9	0.469	0.982
cut	10		1	5	1	3	0	0.400	0.900
date	39		1	15	15	5	3	0.462	0.974
dd	22		1	10	4	3	4	0.489	0.955
df	37		2	13	9	9	4	0.500	0.946
dir	46		4	24	9	4	5	0.402	0.913
dircolors	11		1	6	1	3	0	0.386	0.909
dirname	10		1	5	1	3	0	0.400	0.900
du	73		3	35	22	7	6	0.425	0.959
echo	10		1	5	1	3	0	0.400	0.900

TABLE XIV: Varnode recovery (metatype = STRUCT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
env	17		3	5	2	3	4	0.500	0.824
expand	10		1	5	1	3	0	0.400	0.900
expr	59		1	28	19	6	5	0.441	0.983
factor	32		1	14	14	2	1	0.406	0.969
false	10		1	5	1	3	0	0.400	0.900
fmt	10		1	5	1	3	0	0.400	0.900
fold	10		1	5	1	3	0	0.400	0.900
groups	10		1	5	1	3	0	0.400	0.900
head	12		1	6	2	3	0	0.396	0.917
hostid	10		1	5	1	3	0	0.400	0.900
id	10		1	5	1	3	0	0.400	0.900
join	14		2	7	2	3	0	0.357	0.857
kill	10		1	5	1	3	0	0.400	0.900
link	10		1	5	1	3	0	0.400	0.900
ln	28		2	10	11	4	1	0.429	0.929
logname	10		1	5	1	3	0	0.400	0.900
ls	46		4	24	9	4	5	0.402	0.913
md5sum	12		1	7	1	3	0	0.375	0.917
mkdir	18		1	7	6	4	0	0.431	0.944
mkfifo	12		1	6	2	3	0	0.396	0.917
mknod	12		1	6	2	3	0	0.396	0.917
mktemp	12		1	6	1	3	1	0.438	0.917
mv	53		3	23	19	6	2	0.410	0.943
nice	10		1	5	1	3	0	0.400	0.900
nl	55		4	29	11	6	5	0.405	0.927
nohup	10		1	5	1	3	0	0.400	0.900
nproc	11		1	5	1	3	1	0.455	0.909
numfmt	10		1	5	1	3	0	0.400	0.900
od	13		1	5	4	3	0	0.423	0.923
paste	10		1	5	1	3	0	0.400	0.900
pathchk	13		2	6	1	4	0	0.385	0.846
pinky	12		2	5	2	3	0	0.375	0.833
pr	22		1	11	4	4	2	0.443	0.955
printenv	10		1	5	1	3	0	0.400	0.900
printf	15		1	5	3	6	0	0.483	0.933
ptx	82		1	45	25	6	5	0.405	0.988
pwd	17		1	6	6	4	0	0.441	0.941
readlink	17		2	7	4	4	0	0.397	0.882
realpath	18		2	8	4	4	0	0.389	0.889
rm	23		3	10	5	4	1	0.391	0.870
rmdir	13		1	6	3	3	0	0.404	0.923
runcon	10		1	5	1	3	0	0.400	0.900
seq	17		1	9	4	3	0	0.382	0.941
sha1sum	12		1	7	1	3	0	0.375	0.917
sha224sum	13		1	8	1	3	0	0.365	0.923
sha256sum	13		1	8	1	3	0	0.365	0.923
sha384sum	13		1	5	1	6	0	0.481	0.923
sha512sum	13		1	5	1	6	0	0.481	0.923
shred	15		1	8	3	3	0	0.383	0.933
shuf	15		2	6	3	4	0	0.400	0.867
sleep	13		1	7	1	3	1	0.423	0.923
sort	44		3	17	10	6	8	0.494	0.932
split	15		3	7	1	3	1	0.367	0.800
stat	32		1	13	11	6	1	0.445	0.969
stdbuf	14		1	6	4	3	0	0.411	0.929
stty	18		3	9	3	3	0	0.333	0.833
sum	10		1	5	1	3	0	0.400	0.900

TABLE XIV: Varnode recovery (metatype = STRUCT) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sync	10		1	5	1	3	0	0.400	0.900
tac	53		2	29	11	6	5	0.420	0.962
tail	29		2	15	6	3	3	0.414	0.931
tee	10		1	5	1	3	0	0.400	0.900
test	24		1	14	6	3	0	0.365	0.958
timeout	18		1	6	1	4	6	0.611	0.944
touch	36		1	13	17	4	1	0.438	0.972
tr	13		1	6	1	5	0	0.442	0.923
true	10		1	5	1	3	0	0.400	0.900
truncate	12		1	6	2	3	0	0.396	0.917
tsort	12		1	7	1	3	0	0.375	0.917
tty	10		1	5	1	3	0	0.400	0.900
uname	11		1	5	1	3	1	0.455	0.909
unexpand	10		1	5	1	3	0	0.400	0.900
uniq	12		1	7	1	3	0	0.375	0.917
unlink	10		1	5	1	3	0	0.400	0.900
uptime	15		1	7	4	3	0	0.400	0.933
users	10		1	5	1	3	0	0.400	0.900
vdir	46		4	24	9	4	5	0.402	0.913
wc	16		1	5	3	2	5	0.578	0.938
who	14		2	5	4	3	0	0.393	0.857
whoami	10		1	5	1	3	0	0.400	0.900
yes	10		1	5	1	3	0	0.400	0.900

TABLE XV: Varnode recovery (metatype = UNION) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	0		0	0	0	0	0	-	-
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	0		0	0	0	0	0	-	-
chgrp	0		0	0	0	0	0	-	-
chmod	0		0	0	0	0	0	-	-
chown	0		0	0	0	0	0	-	-
chroot	0		0	0	0	0	0	-	-
cksum	0		0	0	0	0	0	-	-
comm	0		0	0	0	0	0	-	-
cp	1		0	0	0	1	0	0.750	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	0	2	0	0	0.500	1.000
dd	0		0	0	0	0	0	-	-
df	0		0	0	0	0	0	-	-
dir	0		0	0	0	0	0	-	-
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	0		0	0	0	0	0	-	-



TABLE XV: Varnode recovery (metatype = UNION) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	1		0	1	0	0	0	0.250	1.000
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	0		0	0	0	0	0	-	-
logname	0		0	0	0	0	0	-	-
ls	0		0	0	0	0	0	-	-
md5sum	0		0	0	0	0	0	-	-
mkdir	0		0	0	0	0	0	-	-
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	1		0	0	0	1	0	0.750	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	0		0	0	0	0	0	-	-
od	8		0	0	0	8	0	0.750	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	0		0	0	0	0	0	-	-
ptx	1		0	1	0	0	0	0.250	1.000
pwd	0		0	0	0	0	0	-	-
readlink	0		0	0	0	0	0	-	-
realpath	0		0	0	0	0	0	-	-
rm	0		0	0	0	0	0	-	-
rmdir	0		0	0	0	0	0	-	-
runcon	0		0	0	0	0	0	-	-
seq	0		0	0	0	0	0	-	-
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	0		0	0	0	0	0	-	-
shuf	0		0	0	0	0	0	-	-
sleep	0		0	0	0	0	0	-	-
sort	0		0	0	0	0	0	-	-
split	0		0	0	0	0	0	-	-
stat	0		0	0	0	0	0	-	-
stdbuf	0		0	0	0	0	0	-	-
stty	0		0	0	0	0	0	-	-

TABLE XV: Varnode recovery (metatype = UNION) (compilation = stripped)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sum	0		0	0	0	0	0	-	-
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	0		0	0	0	0	0	-	-
tee	0		0	0	0	0	0	-	-
test	0		0	0	0	0	0	-	-
timeout	0		0	0	0	0	0	-	-
touch	2		0	0	2	0	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	0		0	0	0	0	0	-	-
users	0		0	0	0	0	0	-	-
vdir	0		0	0	0	0	0	-	-
wc	0		0	0	0	0	0	-	-
who	0		0	0	0	0	0	-	-
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XVI: Varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partial recovery
[	266		1	18	5	128	114	0.816	0.996
b2sum	237		1	8	7	118	103	0.831	0.996
base32	160		2	6	2	82	68	0.825	0.988
base64	160		1	6	2	82	69	0.831	0.994
basename	129		1	6	2	77	43	0.800	0.992
basenc	219		5	8	2	106	98	0.824	0.977
cat	164		1	6	2	98	57	0.811	0.994
chcon	363		2	14	4	234	109	0.799	0.994
chgrp	339		2	11	5	204	117	0.812	0.994
chmod	347		3	12	7	211	114	0.803	0.991
chown	359		2	12	5	209	131	0.817	0.994
chroot	198		1	8	2	87	100	0.850	0.995
cksum	678		13	24	13	396	232	0.799	0.981
comm	171		1	11	3	103	53	0.787	0.994
cp	703		3	28	12	357	303	0.830	0.996
csplit	982		8	41	15	537	381	0.816	0.992
cut	192		1	7	2	117	65	0.810	0.995
date	747		4	38	26	387	292	0.810	0.995
dd	493		4	18	9	250	212	0.829	0.992
df	640		1	20	11	287	321	0.854	0.998
dir	1031		3	52	13	560	403	0.817	0.997
dircolors	190		2	6	2	115	65	0.809	0.989
dirname	125		1	6	2	74	42	0.800	0.992
du	1499		10	54	28	835	572	0.818	0.993

TABLE XVI: Varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	fraction partial recovery
echo	118		1	6	2	71	38	0.794	0.992
env	201		2	11	3	102	83	0.815	0.990
expand	152		1	7	2	90	52	0.804	0.993
expr	911		8	37	25	492	349	0.812	0.991
factor	511		23	24	22	191	251	0.805	0.955
false	109		1	6	2	66	34	0.789	0.991
fmt	186		1	6	2	110	67	0.817	0.995
fold	143		1	7	2	78	55	0.813	0.993
groups	142		1	6	2	80	53	0.813	0.993
head	215		1	13	2	116	83	0.810	0.995
hostid	118		1	6	4	72	35	0.784	0.992
id	196		1	7	2	102	84	0.833	0.995
join	260		1	8	3	151	97	0.822	0.996
kill	148		3	8	2	79	56	0.799	0.980
link	117		1	6	4	71	35	0.784	0.991
ln	433		2	12	7	233	179	0.832	0.995
logname	118		1	6	4	72	35	0.784	0.992
ls	1031		3	52	13	560	403	0.817	0.997
md5sum	217		2	12	2	120	81	0.806	0.991
mkdir	306		2	12	6	149	137	0.833	0.993
mkfifo	148		2	7	2	86	51	0.799	0.986
mknod	165		2	7	2	89	65	0.815	0.988
mktemp	164		2	6	2	94	60	0.811	0.988
mv	773		4	30	12	433	294	0.818	0.995
nice	130		1	6	2	73	48	0.810	0.992
nl	896		11	36	15	476	358	0.816	0.988
nohup	162		1	7	4	105	45	0.787	0.994
nproc	139		1	6	2	77	53	0.815	0.993
numfmt	291		1	12	3	142	133	0.838	0.997
od	459		2	20	7	209	221	0.842	0.996
paste	142		1	6	2	85	48	0.805	0.993
pathchk	141		1	6	2	88	44	0.798	0.993
pinky	182		1	11	2	110	58	0.793	0.995
pr	543		2	16	8	332	185	0.814	0.996
printenv	119		1	6	2	68	42	0.803	0.992
printf	283		1	17	7	136	122	0.819	0.996
ptx	1126		8	44	28	590	456	0.820	0.993
pwd	143		1	6	3	87	46	0.799	0.993
readlink	243		1	9	5	137	91	0.817	0.996
realpath	248		1	8	5	138	96	0.823	0.996
rm	362		2	10	5	222	123	0.814	0.994
rmdir	234		1	8	5	115	105	0.837	0.996
runcon	121		1	6	2	75	37	0.791	0.992
seq	279		1	20	6	128	124	0.817	0.996
sha1sum	215		2	9	3	116	85	0.817	0.991
sha224sum	225		2	12	3	119	89	0.812	0.991
sha256sum	225		2	12	3	119	89	0.812	0.991
sha384sum	381		3	7	3	278	90	0.792	0.992
sha512sum	381		3	7	3	278	90	0.792	0.992
shred	370		2	18	2	203	145	0.818	0.995
shuf	374		1	7	3	218	145	0.834	0.997
sleep	143		1	8	4	80	50	0.797	0.993
sort	847		7	34	12	467	327	0.817	0.992
split	297		2	12	2	159	122	0.826	0.993
stat	608		5	21	14	321	247	0.822	0.992
stdbuf	267		1	8	6	128	124	0.843	0.996
stty	301		1	13	5	138	144	0.841	0.997
sum	278		2	12	2	140	122	0.831	0.993

TABLE XVI: Varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partially recovered
sync	133		1	7	2	81	42	0.793	0.992
tac	920		8	37	15	505	355	0.816	0.991
tail	423		1	18	5	220	179	0.830	0.998
tee	154		1	8	2	93	50	0.797	0.994
test	260		0	17	4	128	111	0.820	1.000
timeout	175		2	9	2	89	73	0.817	0.989
touch	602		3	33	25	305	236	0.806	0.995
tr	241		1	8	3	117	112	0.843	0.996
true	109		1	6	2	66	34	0.789	0.991
truncate	145		1	6	2	83	53	0.812	0.993
tsort	162		1	9	4	96	52	0.792	0.994
tty	114		1	6	2	69	36	0.792	0.991
uname	120		2	6	2	71	39	0.790	0.983
unexpand	158		1	6	2	92	57	0.813	0.994
uniq	202		1	9	2	115	75	0.814	0.995
unlink	117		1	6	4	71	35	0.784	0.991
uptime	353		1	11	10	218	113	0.805	0.997
users	133		1	6	4	81	41	0.791	0.992
vdir	1031		3	52	13	560	403	0.817	0.997
wc	268		1	7	5	153	102	0.825	0.996
who	282		1	9	5	144	123	0.836	0.996
whoami	120		1	6	4	74	35	0.783	0.992
yes	132		1	6	4	80	41	0.792	0.992

TABLE XVII: Varnode recovery (metatype = INT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	157		0	0	0	83	74	0.868	1.000
b2sum	147		0	0	0	80	67	0.864	1.000
base32	96		0	0	0	51	45	0.867	1.000
base64	96		0	0	0	51	45	0.867	1.000
basename	71		0	0	0	47	24	0.835	1.000
basenc	133		0	1	0	70	62	0.863	1.000
cat	101		0	0	0	64	37	0.842	1.000
chcon	185		0	0	0	124	61	0.832	1.000
chgrp	166		0	0	0	102	64	0.846	1.000
chmod	176		0	0	0	110	66	0.844	1.000
chown	176		0	0	0	103	73	0.854	1.000
chroot	110		0	1	0	53	56	0.873	1.000
cksum	488		2	0	0	329	157	0.827	0.996
comm	104		0	0	0	74	30	0.822	1.000
cp	382		0	1	0	208	173	0.862	1.000
csplit	619		0	1	0	325	293	0.868	1.000
cut	124		0	0	0	81	43	0.837	1.000
date	516		0	10	0	321	185	0.830	1.000
dd	332		0	0	0	187	145	0.859	1.000
df	326		0	0	0	158	168	0.879	1.000
dir	615		0	3	0	368	244	0.847	1.000
dircolors	90		0	0	0	58	32	0.839	1.000
dirname	73		0	0	0	47	26	0.839	1.000
du	931		0	3	0	522	406	0.857	1.000
echo	69		0	0	0	45	24	0.837	1.000

TABLE XVII: Varnode recovery (metatype = INT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
env	112		0	0	0	61	51	0.864	1.000
expand	94		0	0	0	59	35	0.843	1.000
expr	560		0	1	0	286	273	0.871	1.000
factor	343		21	2	0	128	192	0.841	0.939
false	62		0	0	0	40	22	0.839	1.000
fmt	112		0	0	0	72	40	0.839	1.000
fold	88		0	0	0	51	37	0.855	1.000
groups	81		0	0	0	51	30	0.843	1.000
head	138		0	0	0	82	56	0.851	1.000
hostid	67		0	0	0	45	22	0.832	1.000
id	112		0	0	0	69	43	0.846	1.000
join	162		0	0	0	104	58	0.840	1.000
kill	88		0	0	0	52	36	0.852	1.000
link	66		0	0	0	44	22	0.833	1.000
ln	219		0	0	0	125	94	0.857	1.000
logname	66		0	0	0	44	22	0.833	1.000
ls	615		0	3	0	368	244	0.847	1.000
md5sum	139		0	0	0	81	58	0.854	1.000
mkdir	196		0	0	0	102	94	0.870	1.000
mkfifo	88		0	0	0	53	35	0.849	1.000
mknod	100		0	0	0	54	46	0.865	1.000
mktemp	96		0	0	0	60	36	0.844	1.000
mv	428		0	0	0	241	187	0.859	1.000
nice	77		0	0	0	47	30	0.847	1.000
nl	558		0	1	0	288	269	0.870	1.000
nohup	99		0	0	0	71	28	0.821	1.000
nproc	86		0	0	0	51	35	0.852	1.000
numfmt	184		0	0	0	98	86	0.867	1.000
od	294		0	1	0	146	147	0.873	1.000
paste	85		0	0	0	55	30	0.838	1.000
pathchk	85		0	0	0	57	28	0.832	1.000
pinky	96		0	0	0	65	31	0.831	1.000
pr	399		0	1	0	262	136	0.834	1.000
printenv	68		0	0	0	42	26	0.846	1.000
printf	168		0	2	0	85	81	0.865	1.000
ptx	673		0	1	0	347	325	0.870	1.000
pwd	75		0	0	0	50	25	0.833	1.000
readlink	111		0	0	0	69	42	0.845	1.000
realpath	111		0	0	0	65	46	0.854	1.000
rm	185		0	0	0	115	70	0.845	1.000
rmdir	139		0	0	0	73	66	0.869	1.000
runcon	65		0	0	0	42	23	0.838	1.000
seq	156		0	0	0	81	75	0.870	1.000
sha1sum	138		0	0	0	78	60	0.859	1.000
sha224sum	145		0	0	0	80	65	0.862	1.000
sha256sum	145		0	0	0	80	65	0.862	1.000
sha384sum	301		0	0	0	236	65	0.804	1.000
sha512sum	301		0	0	0	236	65	0.804	1.000
shred	238		0	0	0	140	98	0.853	1.000
shuf	210		0	0	0	129	81	0.846	1.000
sleep	76		0	0	0	49	27	0.839	1.000
sort	440		0	0	0	260	180	0.852	1.000
split	195		0	0	0	109	86	0.860	1.000
stat	392		0	1	0	237	154	0.847	1.000
stdbuf	156		0	0	0	80	76	0.872	1.000
stty	189		0	1	0	89	99	0.878	1.000
sum	183		0	0	0	99	84	0.865	1.000

TABLE XVII: Varnode recovery (metatype = INT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
sync	83		0	0	0	54	29	0.837	1.000
tac	584		0	1	0	310	273	0.866	1.000
tail	239		0	0	0	141	98	0.853	1.000
tee	95		0	0	0	62	33	0.837	1.000
test	155		0	0	0	83	72	0.866	1.000
timeout	95		0	0	0	55	40	0.855	1.000
touch	396		0	9	0	244	143	0.829	1.000
tr	153		0	0	0	70	83	0.886	1.000
true	62		0	0	0	40	22	0.839	1.000
truncate	91		0	0	0	55	36	0.849	1.000
tsort	85		0	0	0	55	30	0.838	1.000
tty	65		0	0	0	43	22	0.835	1.000
uname	67		0	0	0	43	24	0.840	1.000
unexpand	101		0	0	0	61	40	0.849	1.000
uniq	125		0	0	0	79	46	0.842	1.000
unlink	66		0	0	0	44	22	0.833	1.000
uptime	261		0	1	0	174	86	0.830	1.000
users	73		0	0	0	47	26	0.839	1.000
vdir	615		0	3	0	368	244	0.847	1.000
wc	148		0	0	0	90	58	0.848	1.000
who	158		0	0	0	90	68	0.858	1.000
whoami	68		0	0	0	46	22	0.831	1.000
yes	76		0	0	0	50	26	0.836	1.000

TABLE XVIII: Varnode recovery (metatype = FLOAT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	2		0	1	0	1	0	0.500	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	3		0	0	0	3	0	0.750	1.000
chgrp	3		0	0	0	3	0	0.750	1.000
chmod	3		0	0	0	3	0	0.750	1.000
chown	3		0	0	0	3	0	0.750	1.000
chroot	0		0	0	0	0	0	-	-
cksum	3		0	2	0	1	0	0.417	1.000
comm	0		0	0	0	0	0	-	-
cp	3		0	0	0	3	0	0.750	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	1	0	1	0	0.500	1.000
dd	7		0	3	0	4	0	0.536	1.000
df	13		0	3	0	5	5	0.731	1.000
dir	6		0	2	0	4	0	0.583	1.000
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	6		0	2	0	4	0	0.583	1.000

TABLE XVIII: Varnode recovery (metatype = FLOAT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	3		0	0	0	3	0	0.750	1.000
logname	0		0	0	0	0	0	-	-
ls	6		0	2	0	4	0	0.583	1.000
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	1	0	1	0	0.500	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	3		0	0	0	3	0	0.750	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	5	0	2	0	0.393	1.000
od	11		0	3	0	8	0	0.614	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	5	0	2	0	0.393	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	3		0	0	0	3	0	0.750	1.000
realpath	3		0	0	0	3	0	0.750	1.000
rm	3		0	0	0	3	0	0.750	1.000
rmdir	2		0	1	0	1	0	0.500	1.000
runcon	0		0	0	0	0	0	-	-
seq	10		0	9	0	1	0	0.300	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	2	0	1	0	0.417	1.000
shuf	3		0	0	0	3	0	0.750	1.000
sleep	7		0	0	0	2	5	0.929	1.000
sort	18		0	4	0	12	2	0.667	1.000
split	0		0	0	0	0	0	-	-
stat	2		0	1	0	1	0	0.500	1.000
stdbuf	2		0	1	0	1	0	0.500	1.000
stty	2		0	1	0	1	0	0.500	1.000

TABLE XVIII: Varnode recovery (metatype = FLOAT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sum	3		0	2	0	1	0	0.417	1.000
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	11		0	0	0	6	5	0.864	1.000
tee	0		0	0	0	0	0	-	-
test	2		0	1	0	1	0	0.500	1.000
timeout	8		0	0	0	4	4	0.875	1.000
touch	2		0	1	0	1	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	2		0	0	0	1	1	0.875	1.000
users	0		0	0	0	0	0	-	-
vdir	6		0	2	0	4	0	0.583	1.000
wc	4		0	0	0	4	0	0.750	1.000
who	2		0	1	0	1	0	0.500	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XIX: Varnode recovery (metatype = POINTER) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	68		0	0	0	38	30	0.860	1.000
b2sum	56		0	0	0	32	24	0.857	1.000
base32	41		0	0	0	24	17	0.854	1.000
base64	41		0	0	0	24	17	0.854	1.000
basename	38		0	0	0	24	14	0.842	1.000
basenc	55		0	0	0	30	25	0.864	1.000
cat	41		0	0	0	28	13	0.829	1.000
chcon	134		1	0	0	93	40	0.819	0.993
chgrp	133		1	0	0	90	42	0.823	0.992
chmod	127		1	0	0	89	37	0.817	0.992
chown	142		1	0	0	94	47	0.827	0.993
chroot	67		0	0	0	28	39	0.896	1.000
cksum	99		0	0	0	56	43	0.859	1.000
comm	35		0	0	0	22	13	0.843	1.000
cp	231		0	0	0	132	99	0.857	1.000
csplit	272		6	0	0	202	64	0.792	0.978
cut	46		0	0	0	29	17	0.842	1.000
date	125		0	0	0	57	68	0.886	1.000
dd	98		0	0	0	50	48	0.872	1.000
df	239		0	0	0	110	129	0.885	1.000
dir	293		0	0	0	173	120	0.852	1.000
dircolors	76		0	0	0	50	26	0.836	1.000



TABLE XIX: Varnode recovery (metatype = POINTER) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
dirname	32	0	0	0	0	21	11	0.836	1.000
du	438	7	0	0	0	296	135	0.815	0.984
echo	30	0	0	0	0	20	10	0.833	1.000
env	54	0	0	0	0	32	22	0.852	1.000
expand	35	0	0	0	0	25	10	0.821	1.000
expr	259	6	0	0	0	197	56	0.787	0.977
factor	98	1	0	0	0	57	40	0.844	0.990
false	28	0	0	0	0	20	8	0.821	1.000
fmt	52	0	0	0	0	32	20	0.846	1.000
fold	33	0	0	0	0	21	12	0.841	1.000
groups	40	0	0	0	0	23	17	0.856	1.000
head	47	0	0	0	0	28	19	0.851	1.000
hostid	29	0	0	0	0	21	8	0.819	1.000
id	60	0	0	0	0	27	33	0.887	1.000
join	66	0	0	0	0	38	28	0.856	1.000
kill	36	0	0	0	0	21	15	0.854	1.000
link	29	0	0	0	0	21	8	0.819	1.000
ln	161	0	0	0	0	95	66	0.852	1.000
logname	30	0	0	0	0	22	8	0.817	1.000
ls	293	0	0	0	0	173	120	0.852	1.000
md5sum	50	0	0	0	0	33	17	0.835	1.000
mkdir	71	0	0	0	0	39	32	0.863	1.000
mkfifo	36	0	0	0	0	27	9	0.812	1.000
mknod	41	0	0	0	0	29	12	0.823	1.000
mktemp	44	0	0	0	0	28	16	0.841	1.000
mv	254	1	0	0	0	174	79	0.825	0.996
nice	33	0	0	0	0	20	13	0.848	1.000
nl	247	6	0	0	0	174	67	0.800	0.976
nohup	40	0	0	0	0	28	12	0.825	1.000
nproc	32	0	0	0	0	20	12	0.844	1.000
numfmt	70	0	0	0	0	36	34	0.871	1.000
od	93	0	0	0	0	40	53	0.892	1.000
paste	37	0	0	0	0	24	13	0.838	1.000
pathchk	33	0	0	0	0	23	10	0.826	1.000
pinky	57	0	0	0	0	38	19	0.833	1.000
pr	102	0	0	0	0	63	39	0.846	1.000
printenv	31	0	0	0	0	20	11	0.839	1.000
printf	76	0	2	0	0	40	34	0.849	1.000
ptx	331	6	0	0	0	219	106	0.816	0.982
pwd	41	0	0	0	0	30	11	0.817	1.000
readlink	100	0	0	0	0	57	43	0.858	1.000
realpath	105	0	0	0	0	62	43	0.852	1.000
rm	136	1	0	0	0	95	40	0.818	0.993
rmdir	66	0	0	0	0	35	31	0.867	1.000
runcon	36	0	0	0	0	27	9	0.812	1.000
seq	81	0	1	0	0	39	41	0.870	1.000
sha1sum	49	0	0	0	0	32	17	0.837	1.000
sha224sum	50	0	0	0	0	33	17	0.835	1.000
sha256sum	50	0	0	0	0	33	17	0.835	1.000
sha384sum	50	0	0	0	0	33	17	0.835	1.000
sha512sum	50	0	0	0	0	33	17	0.835	1.000
shred	87	0	0	0	0	55	32	0.842	1.000
shuf	134	0	0	0	0	78	56	0.854	1.000
sleep	35	0	0	0	0	23	12	0.836	1.000
sort	299	0	0	0	0	181	118	0.849	1.000
split	69	0	0	0	0	41	28	0.851	1.000

TABLE XIX: Varnode recovery (metatype = POINTER) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
stat	150		0	0	0	74	76	0.877	1.000
stdbuf	79		0	0	0	40	39	0.873	1.000
stty	73		0	0	0	39	34	0.866	1.000
sum	60		0	0	0	33	27	0.863	1.000
sync	29		0	0	0	21	8	0.819	1.000
tac	250		6	0	0	184	60	0.792	0.976
tail	124		0	1	0	65	58	0.863	1.000
tee	35		0	0	0	25	10	0.821	1.000
test	67		0	0	0	38	29	0.858	1.000
timeout	41		0	0	0	23	18	0.860	1.000
touch	110		0	0	0	53	57	0.880	1.000
tr	58		0	0	0	39	19	0.832	1.000
true	28		0	0	0	20	8	0.821	1.000
truncate	32		0	0	0	22	10	0.828	1.000
tsort	52		0	0	0	35	17	0.832	1.000
tty	29		0	0	0	20	9	0.828	1.000
uname	30		0	0	0	22	8	0.817	1.000
unexpand	36		0	0	0	25	11	0.826	1.000
uniq	50		0	0	0	30	20	0.850	1.000
unlink	29		0	0	0	21	8	0.819	1.000
uptime	57		0	0	0	37	20	0.838	1.000
users	38		0	0	0	28	10	0.816	1.000
vdir	293		0	0	0	173	120	0.852	1.000
wc	84		0	0	0	52	32	0.845	1.000
who	83		0	0	0	44	39	0.867	1.000
whoami	30		0	0	0	22	8	0.817	1.000
yes	34		0	0	0	24	10	0.824	1.000

TABLE XX: Varnode recovery (metatype = ARRAY) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	15		1	5	3	0	6	0.583	0.933
b2sum	24		1	4	7	0	12	0.688	0.958
base32	12		2	2	2	0	6	0.625	0.833
base64	12		1	2	2	0	7	0.708	0.917
basename	10		1	2	2	0	5	0.650	0.900
basenc	20		5	2	2	0	11	0.625	0.750
cat	11		1	2	2	0	6	0.682	0.909
chcon	18		1	10	2	0	5	0.472	0.944
chgrp	15		1	7	2	0	5	0.517	0.933
chmod	19		2	8	4	0	5	0.474	0.895
chown	16		1	8	2	0	5	0.500	0.938
chroot	11		1	3	2	0	5	0.614	0.909
cksum	66		11	9	13	1	32	0.629	0.833
comm	22		1	7	3	1	10	0.636	0.955
cp	40		3	13	4	3	17	0.613	0.925
csplit	35		2	13	5	0	15	0.593	0.943
cut	12		1	3	2	1	5	0.625	0.917
date	63		4	14	10	0	35	0.690	0.937
dd	34		4	7	6	2	15	0.625	0.882

TABLE XX: Varnode recovery (metatype = ARRAY) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
df	25		1	9	3	2	10	0.610	0.960
dir	71		3	27	6	3	32	0.620	0.958
dircolors	13		2	2	2	0	7	0.654	0.846
dirname	10		1	2	2	0	5	0.650	0.900
du	51		3	16	8	1	23	0.623	0.941
echo	9		1	2	2	0	4	0.611	0.889
env	18		2	7	2	1	6	0.528	0.889
expand	13		1	3	2	0	7	0.673	0.923
expr	33		2	9	7	0	15	0.629	0.939
factor	37		1	9	9	0	18	0.669	0.973
false	9		1	2	2	0	4	0.611	0.889
fmt	12		1	2	2	0	7	0.708	0.917
fold	12		1	3	2	0	6	0.646	0.917
groups	11		1	2	2	0	6	0.682	0.909
head	18		1	9	2	0	6	0.514	0.944
hostid	12		1	2	4	0	5	0.625	0.917
id	14		1	3	2	0	8	0.696	0.929
join	18		1	3	2	1	11	0.750	0.944
kill	14		3	4	2	0	5	0.500	0.786
link	12		1	2	4	0	5	0.625	0.917
ln	22		2	6	2	3	9	0.625	0.909
logname	12		1	2	4	0	5	0.625	0.917
ls	71		3	27	6	3	32	0.620	0.958
md5sum	16		2	6	2	0	6	0.531	0.875
mkdir	19		2	7	3	0	7	0.539	0.895
mkfifo	12		2	3	2	0	5	0.562	0.833
mknod	12		2	3	2	0	5	0.562	0.833
mktemp	12		2	2	2	0	6	0.625	0.833
mv	34		3	13	4	3	11	0.544	0.912
nice	10		1	2	2	0	5	0.650	0.900
nl	36		5	8	5	1	17	0.618	0.861
nohup	13		1	3	4	0	5	0.596	0.923
nproc	10		1	2	2	0	5	0.650	0.900
numfmt	20		1	3	3	0	13	0.762	0.950
od	40		2	12	5	1	20	0.656	0.950
paste	10		1	2	2	0	5	0.650	0.900
pathchk	10		1	2	2	0	5	0.650	0.900
pinky	17		1	7	2	0	7	0.574	0.941
pr	20		2	6	5	0	7	0.550	0.900
printenv	10		1	2	2	0	5	0.650	0.900
printf	17		1	4	5	0	7	0.618	0.941
ptx	39		2	9	5	4	19	0.686	0.949
pwd	10		1	2	2	0	5	0.650	0.900
readlink	12		1	3	2	1	5	0.625	0.917
realpath	11		1	2	2	1	5	0.659	0.909
rm	15		1	5	2	0	7	0.617	0.933
rmdir	14		1	3	3	0	7	0.661	0.929
runcon	10		1	2	2	0	5	0.650	0.900
seq	15		1	2	3	1	8	0.717	0.933
sha1sum	16		2	3	3	0	8	0.641	0.875
sha224sum	17		2	5	3	0	7	0.574	0.882
sha256sum	17		2	5	3	0	7	0.574	0.882
sha384sum	17		3	3	3	0	8	0.603	0.824
sha512sum	17		3	3	3	0	8	0.603	0.824
shred	27		2	10	2	1	12	0.602	0.926
shuf	12		1	3	2	0	6	0.646	0.917
sleep	12		1	2	4	0	5	0.625	0.917

TABLE XX: Varnode recovery (metatype = ARRAY) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
sort	46		6	17	5	1	17	0.533	0.870
split	18		2	7	2	0	7	0.542	0.889
stat	32		5	7	6	0	14	0.586	0.844
stdbuf	16		1	3	4	0	8	0.672	0.938
stty	19		1	4	3	0	11	0.711	0.947
sum	22		2	6	2	1	11	0.648	0.909
sync	11		1	3	2	0	5	0.614	0.909
tac	33		2	9	5	0	17	0.659	0.939
tail	20		1	9	3	1	6	0.525	0.950
tee	14		1	4	2	0	7	0.643	0.929
test	12		0	4	2	0	6	0.667	1.000
timeout	13		2	4	2	0	5	0.538	0.846
touch	56		3	13	7	0	33	0.710	0.946
tr	17		1	3	3	0	10	0.721	0.941
true	9		1	2	2	0	4	0.611	0.889
truncate	10		1	2	2	0	5	0.650	0.900
tsort	13		1	3	4	0	5	0.596	0.923
tty	10		1	2	2	0	5	0.650	0.900
uname	12		2	2	2	0	6	0.625	0.833
unexpand	11		1	2	2	0	6	0.682	0.909
uniq	15		1	3	2	0	9	0.717	0.933
unlink	12		1	2	4	0	5	0.625	0.917
uptime	18		1	4	7	0	6	0.583	0.944
users	12		1	2	4	0	5	0.625	0.917
vdir	71		3	27	6	3	32	0.620	0.958
wc	16		1	3	4	2	6	0.641	0.938
who	25		1	4	3	2	15	0.760	0.960
whoami	12		1	2	4	0	5	0.625	0.917
yes	12		1	2	4	0	5	0.625	0.917

TABLE XXI: Varnode recovery (metatype = STRUCT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	24		0	12	2	6	4	0.521	1.000
b2sum	10		0	4	0	6	0	0.550	1.000
base32	11		0	4	0	7	0	0.568	1.000
base64	11		0	4	0	7	0	0.568	1.000
basename	10		0	4	0	6	0	0.550	1.000
basenc	11		0	5	0	6	0	0.523	1.000
cat	11		0	4	0	6	1	0.591	1.000
chcon	23		0	4	2	14	3	0.674	1.000
chgrp	22		0	4	3	9	6	0.693	1.000
chmod	22		0	4	3	9	6	0.693	1.000
chown	22		0	4	3	9	6	0.693	1.000
chroot	10		0	4	0	6	0	0.550	1.000
cksum	22		0	13	0	9	0	0.455	1.000
comm	10		0	4	0	6	0	0.550	1.000
cp	46		0	14	8	10	14	0.630	1.000
csplit	56		0	27	10	10	9	0.504	1.000
cut	10		0	4	0	6	0	0.550	1.000

TABLE XXI: Varnode recovery (metatype = STRUCT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
date	39		0	13	14	8	4	0.519	1.000
dd	22		0	8	3	7	4	0.580	1.000
df	37		0	8	8	12	9	0.649	1.000
dir	46		0	20	7	12	7	0.533	1.000
dircolors	11		0	4	0	7	0	0.568	1.000
dirname	10		0	4	0	6	0	0.550	1.000
du	73		0	33	20	12	8	0.483	1.000
echo	10		0	4	0	6	0	0.550	1.000
env	17		0	4	1	8	4	0.676	1.000
expand	10		0	4	0	6	0	0.550	1.000
expr	59		0	27	18	9	5	0.466	1.000
factor	32		0	12	13	6	1	0.469	1.000
false	10		0	4	0	6	0	0.550	1.000
fmt	10		0	4	0	6	0	0.550	1.000
fold	10		0	4	0	6	0	0.550	1.000
groups	10		0	4	0	6	0	0.550	1.000
head	12		0	4	0	6	2	0.625	1.000
hostid	10		0	4	0	6	0	0.550	1.000
id	10		0	4	0	6	0	0.550	1.000
join	14		0	5	1	8	0	0.554	1.000
kill	10		0	4	0	6	0	0.550	1.000
link	10		0	4	0	6	0	0.550	1.000
ln	28		0	6	5	7	10	0.688	1.000
logname	10		0	4	0	6	0	0.550	1.000
ls	46		0	20	7	12	7	0.533	1.000
md5sum	12		0	6	0	6	0	0.500	1.000
mkdir	18		0	4	3	7	4	0.653	1.000
mkfifo	12		0	4	0	6	2	0.625	1.000
mknod	12		0	4	0	6	2	0.625	1.000
mktemp	12		0	4	0	6	2	0.625	1.000
mv	53		0	17	8	11	17	0.632	1.000
nice	10		0	4	0	6	0	0.550	1.000
nl	55		0	27	10	13	5	0.482	1.000
nohup	10		0	4	0	6	0	0.550	1.000
nproc	11		0	4	0	6	1	0.591	1.000
numfmt	10		0	4	0	6	0	0.550	1.000
od	13		0	4	2	6	1	0.577	1.000
paste	10		0	4	0	6	0	0.550	1.000
pathchk	13		0	4	0	8	1	0.615	1.000
pinky	12		0	4	0	7	1	0.604	1.000
pr	22		0	9	3	7	3	0.545	1.000
printenv	10		0	4	0	6	0	0.550	1.000
printf	15		0	4	2	9	0	0.583	1.000
ptx	82		0	33	23	20	6	0.497	1.000
pwd	17		0	4	1	7	5	0.691	1.000
readlink	17		0	6	3	7	1	0.544	1.000
realpath	18		0	6	3	7	2	0.569	1.000
rm	23		0	5	3	9	6	0.674	1.000
rmdir	13		0	4	2	6	1	0.577	1.000
runcon	10		0	4	0	6	0	0.550	1.000
seq	17		0	8	3	6	0	0.471	1.000
sha1sum	12		0	6	0	6	0	0.500	1.000
sha224sum	13		0	7	0	6	0	0.481	1.000
sha256sum	13		0	7	0	6	0	0.481	1.000
sha384sum	13		0	4	0	9	0	0.596	1.000
sha512sum	13		0	4	0	9	0	0.596	1.000

TABLE XXI: Varnode recovery (metatype = STRUCT) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
shred	15		0	6	0	6	3	0.600	1.000
shuf	15		0	4	1	8	2	0.633	1.000
sleep	13		0	6	0	6	1	0.538	1.000
sort	44		1	13	7	13	10	0.602	0.977
split	15		0	5	0	9	1	0.600	1.000
stat	32		0	12	8	9	3	0.523	1.000
stdbuf	14		0	4	2	7	1	0.589	1.000
stty	18		0	7	2	9	0	0.528	1.000
sum	10		0	4	0	6	0	0.550	1.000
sync	10		0	4	0	6	0	0.550	1.000
tac	53		0	27	10	11	5	0.472	1.000
tail	29		0	8	2	7	12	0.698	1.000
tee	10		0	4	0	6	0	0.550	1.000
test	24		0	12	2	6	4	0.521	1.000
timeout	18		0	5	0	7	6	0.694	1.000
touch	36		0	10	16	7	3	0.521	1.000
tr	13		0	5	0	8	0	0.558	1.000
true	10		0	4	0	6	0	0.550	1.000
truncate	12		0	4	0	6	2	0.625	1.000
tsort	12		0	6	0	6	0	0.500	1.000
tty	10		0	4	0	6	0	0.550	1.000
uname	11		0	4	0	6	1	0.591	1.000
unexpand	10		0	4	0	6	0	0.550	1.000
uniq	12		0	6	0	6	0	0.500	1.000
unlink	10		0	4	0	6	0	0.550	1.000
uptime	15		0	6	3	6	0	0.500	1.000
users	10		0	4	0	6	0	0.550	1.000
vdir	46		0	20	7	12	7	0.533	1.000
wc	16		0	4	1	5	6	0.703	1.000
who	14		0	4	2	7	1	0.589	1.000
whoami	10		0	4	0	6	0	0.550	1.000
yes	10		0	4	0	6	0	0.550	1.000

TABLE XXII: Varnode recovery (metatype = UNION) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	0		0	0	0	0	0	-	-
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	0		0	0	0	0	0	-	-
chgrp	0		0	0	0	0	0	-	-
chmod	0		0	0	0	0	0	-	-
chown	0		0	0	0	0	0	-	-
chroot	0		0	0	0	0	0	-	-
cksum	0		0	0	0	0	0	-	-
comm	0		0	0	0	0	0	-	-

TABLE XXII: Varnode recovery (metatype = UNION) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
cp	1		0	0	0	1	0	0.750	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	0	2	0	0	0.500	1.000
dd	0		0	0	0	0	0	-	-
df	0		0	0	0	0	0	-	-
dir	0		0	0	0	0	0	-	-
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	0		0	0	0	0	0	-	-
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	1		0	1	0	0	0	0.250	1.000
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	0		0	0	0	0	0	-	-
logname	0		0	0	0	0	0	-	-
ls	0		0	0	0	0	0	-	-
md5sum	0		0	0	0	0	0	-	-
mkdir	0		0	0	0	0	0	-	-
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	1		0	0	0	1	0	0.750	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	0		0	0	0	0	0	-	-
od	8		0	0	0	8	0	0.750	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	0		0	0	0	0	0	-	-
ptx	1		0	1	0	0	0	0.250	1.000
pwd	0		0	0	0	0	0	-	-
readlink	0		0	0	0	0	0	-	-
realpath	0		0	0	0	0	0	-	-
rm	0		0	0	0	0	0	-	-
rmdir	0		0	0	0	0	0	-	-
runcon	0		0	0	0	0	0	-	-
seq	0		0	0	0	0	0	-	-
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-

TABLE XXII: Varnode recovery (metatype = UNION) (compilation = standard)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	0		0	0	0	0	0	-	-
shuf	0		0	0	0	0	0	-	-
sleep	0		0	0	0	0	0	-	-
sort	0		0	0	0	0	0	-	-
split	0		0	0	0	0	0	-	-
stat	0		0	0	0	0	0	-	-
stdbuf	0		0	0	0	0	0	-	-
stty	0		0	0	0	0	0	-	-
sum	0		0	0	0	0	0	-	-
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	0		0	0	0	0	0	-	-
tee	0		0	0	0	0	0	-	-
test	0		0	0	0	0	0	-	-
timeout	0		0	0	0	0	0	-	-
touch	2		0	0	2	0	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	0		0	0	0	0	0	-	-
users	0		0	0	0	0	0	-	-
vdir	0		0	0	0	0	0	-	-
wc	0		0	0	0	0	0	-	-
who	0		0	0	0	0	0	-	-
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XXIII: Varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partial recovery
[	266		0	0	0	0	266	1.000	1.000
b2sum	237		0	0	0	0	237	1.000	1.000
base32	160		0	0	0	0	160	1.000	1.000
base64	160		0	0	0	0	160	1.000	1.000
basename	129		0	0	0	0	129	1.000	1.000
basenc	219		0	0	0	0	219	1.000	1.000
cat	164		0	0	0	0	164	1.000	1.000
chcon	363		0	0	0	0	363	1.000	1.000
chgrp	339		0	0	0	0	339	1.000	1.000
chmod	347		0	0	0	0	347	1.000	1.000
chown	359		0	0	0	0	359	1.000	1.000
chroot	198		0	1	0	0	197	0.996	1.000
cksum	678		0	0	0	0	678	1.000	1.000
comm	171		0	0	0	0	171	1.000	1.000



TABLE XXIII: Varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	aver- age	Varnode fraction partial recovery
cp	703		0	2	0	2	699	0.997		1.000
csplit	982		0	1	1	0	980	0.999		1.000
cut	192		0	0	0	0	192	1.000		1.000
date	747		0	8	2	0	737	0.991		1.000
dd	493		0	0	0	0	493	1.000		1.000
df	640		0	2	0	0	638	0.998		1.000
dir	1031		0	4	3	0	1024	0.996		1.000
dircolors	190		0	0	0	0	190	1.000		1.000
dirname	125		0	0	0	0	125	1.000		1.000
du	1499		0	2	2	0	1495	0.998		1.000
echo	118		0	0	0	0	118	1.000		1.000
env	201		0	0	0	0	201	1.000		1.000
expand	152		0	0	0	0	152	1.000		1.000
expr	911		0	1	1	0	909	0.999		1.000
factor	511	23	1	0	0	0	487	0.954		0.955
false	109		0	0	0	0	109	1.000		1.000
fmt	186		0	0	0	0	186	1.000		1.000
fold	143		0	0	0	0	143	1.000		1.000
groups	142		0	0	0	0	142	1.000		1.000
head	215		0	0	0	0	215	1.000		1.000
hostid	118		0	0	0	0	118	1.000		1.000
id	196		0	0	0	0	196	1.000		1.000
join	260		0	0	0	0	260	1.000		1.000
kill	148		0	0	0	0	148	1.000		1.000
link	117		0	0	0	0	117	1.000		1.000
ln	433		0	0	0	0	433	1.000		1.000
logname	118		0	0	0	0	118	1.000		1.000
ls	1031		0	4	3	0	1024	0.996		1.000
md5sum	217		0	0	0	0	217	1.000		1.000
mkdir	306		0	1	0	0	305	0.998		1.000
mkfifo	148		0	0	0	0	148	1.000		1.000
mknod	165		0	0	0	0	165	1.000		1.000
mktemp	164		0	0	0	0	164	1.000		1.000
mv	773		0	1	0	2	770	0.998		1.000
nice	130		0	0	0	0	130	1.000		1.000
nl	896		0	1	1	0	894	0.999		1.000
nohup	162		0	0	0	0	162	1.000		1.000
nproc	139		0	0	0	0	139	1.000		1.000
numfmt	291		0	0	0	0	291	1.000		1.000
od	459		0	1	0	0	458	0.998		1.000
paste	142		0	0	0	0	142	1.000		1.000
pathchk	141		0	0	0	0	141	1.000		1.000
pinky	182		0	0	1	0	181	0.997		1.000
pr	543		0	0	1	0	542	0.999		1.000
printenv	119		0	0	0	0	119	1.000		1.000
printf	283		0	3	0	0	280	0.992		1.000
ptx	1126		0	2	1	0	1123	0.998		1.000
pwd	143		0	0	0	0	143	1.000		1.000
readlink	243		0	0	0	0	243	1.000		1.000
realpath	248		0	0	0	0	248	1.000		1.000
rm	362		0	0	0	0	362	1.000		1.000
rmdir	234		0	0	0	0	234	1.000		1.000
runcon	121		0	0	0	0	121	1.000		1.000
seq	279		0	0	0	0	279	1.000		1.000
sha1sum	215		0	0	0	0	215	1.000		1.000
sha224sum	225		0	0	0	0	225	1.000		1.000
sha256sum	225		0	0	0	0	225	1.000		1.000
sha384sum	381		0	0	0	0	381	1.000		1.000

TABLE XXIII: Varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode frac- tion partial recovery
sha512sum	381		0	0	0	0	381	1.000	1.000
shred	370		0	0	1	0	369	0.999	1.000
shuf	374		0	0	0	0	374	1.000	1.000
sleep	143		0	0	0	0	143	1.000	1.000
sort	847		0	2	0	0	845	0.998	1.000
split	297		0	1	0	0	296	0.997	1.000
stat	608		0	0	1	0	607	0.999	1.000
stdbuf	267		0	0	0	0	267	1.000	1.000
stty	301		0	0	0	0	301	1.000	1.000
sum	278		0	0	0	0	278	1.000	1.000
sync	133		0	0	0	0	133	1.000	1.000
tac	920		0	1	1	0	918	0.999	1.000
tail	423		0	1	0	0	422	0.998	1.000
tee	154		0	0	0	0	154	1.000	1.000
test	260		0	0	0	0	260	1.000	1.000
timeout	175		0	0	0	0	175	1.000	1.000
touch	602		0	8	1	2	591	0.988	1.000
tr	241		0	0	0	0	241	1.000	1.000
true	109		0	0	0	0	109	1.000	1.000
truncate	145		0	0	0	0	145	1.000	1.000
tsort	162		0	0	0	0	162	1.000	1.000
tty	114		0	0	0	0	114	1.000	1.000
uname	120		0	0	0	0	120	1.000	1.000
unexpand	158		0	0	0	0	158	1.000	1.000
uniq	202		0	0	0	0	202	1.000	1.000
unlink	117		0	0	0	0	117	1.000	1.000
uptime	353		0	0	1	1	351	0.998	1.000
users	133		0	0	0	0	133	1.000	1.000
vdir	1031		0	4	3	0	1024	0.996	1.000
wc	268		0	0	0	0	268	1.000	1.000
who	282		0	0	0	0	282	1.000	1.000
whoami	120		0	0	0	0	120	1.000	1.000
yes	132		0	0	0	0	132	1.000	1.000

TABLE XXIV: Varnode recovery (metatype = INT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode frac- tion partial recovery
[	157		0	0	0	0	157	1.000	1.000
b2sum	147		0	0	0	0	147	1.000	1.000
base32	96		0	0	0	0	96	1.000	1.000
base64	96		0	0	0	0	96	1.000	1.000
basename	71		0	0	0	0	71	1.000	1.000
basenc	133		0	0	0	0	133	1.000	1.000
cat	101		0	0	0	0	101	1.000	1.000
chcon	185		0	0	0	0	185	1.000	1.000
chgrp	166		0	0	0	0	166	1.000	1.000
chmod	176		0	0	0	0	176	1.000	1.000
chown	176		0	0	0	0	176	1.000	1.000
chroot	110		0	1	0	0	109	0.993	1.000
cksum	488		0	0	0	0	488	1.000	1.000
comm	104		0	0	0	0	104	1.000	1.000
cp	382		0	1	0	2	379	0.997	1.000

TABLE XXIV: Varnode recovery (metatype = INT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
csplit	619		0	1	0	0	618	0.999	1.000
cut	124		0	0	0	0	124	1.000	1.000
date	516		0	5	0	0	511	0.993	1.000
dd	332		0	0	0	0	332	1.000	1.000
df	326		0	0	0	0	326	1.000	1.000
dir	615		0	1	0	0	614	0.999	1.000
dircolors	90		0	0	0	0	90	1.000	1.000
dirname	73		0	0	0	0	73	1.000	1.000
du	931		0	2	0	0	929	0.998	1.000
echo	69		0	0	0	0	69	1.000	1.000
env	112		0	0	0	0	112	1.000	1.000
expand	94		0	0	0	0	94	1.000	1.000
expr	560		0	1	0	0	559	0.999	1.000
factor	343		13	0	0	0	330	0.962	0.962
false	62		0	0	0	0	62	1.000	1.000
fmt	112		0	0	0	0	112	1.000	1.000
fold	88		0	0	0	0	88	1.000	1.000
groups	81		0	0	0	0	81	1.000	1.000
head	138		0	0	0	0	138	1.000	1.000
hostid	67		0	0	0	0	67	1.000	1.000
id	112		0	0	0	0	112	1.000	1.000
join	162		0	0	0	0	162	1.000	1.000
kill	88		0	0	0	0	88	1.000	1.000
link	66		0	0	0	0	66	1.000	1.000
ln	219		0	0	0	0	219	1.000	1.000
logname	66		0	0	0	0	66	1.000	1.000
ls	615		0	1	0	0	614	0.999	1.000
md5sum	139		0	0	0	0	139	1.000	1.000
mkdir	196		0	0	0	0	196	1.000	1.000
mkfifo	88		0	0	0	0	88	1.000	1.000
mknod	100		0	0	0	0	100	1.000	1.000
mktemp	96		0	0	0	0	96	1.000	1.000
mv	428		0	0	0	2	426	0.999	1.000
nice	77		0	0	0	0	77	1.000	1.000
nl	558		0	1	0	0	557	0.999	1.000
nohup	99		0	0	0	0	99	1.000	1.000
nproc	86		0	0	0	0	86	1.000	1.000
numfmt	184		0	0	0	0	184	1.000	1.000
od	294		0	1	0	0	293	0.997	1.000
paste	85		0	0	0	0	85	1.000	1.000
pathchk	85		0	0	0	0	85	1.000	1.000
pinky	96		0	0	0	0	96	1.000	1.000
pr	399		0	0	0	0	399	1.000	1.000
printenv	68		0	0	0	0	68	1.000	1.000
printf	168		0	3	0	0	165	0.987	1.000
ptx	673		0	1	0	0	672	0.999	1.000
pwd	75		0	0	0	0	75	1.000	1.000
readlink	111		0	0	0	0	111	1.000	1.000
realpath	111		0	0	0	0	111	1.000	1.000
rm	185		0	0	0	0	185	1.000	1.000
rmdir	139		0	0	0	0	139	1.000	1.000
runcon	65		0	0	0	0	65	1.000	1.000
seq	156		0	0	0	0	156	1.000	1.000
sha1sum	138		0	0	0	0	138	1.000	1.000
sha224sum	145		0	0	0	0	145	1.000	1.000
sha256sum	145		0	0	0	0	145	1.000	1.000
sha384sum	301		0	0	0	0	301	1.000	1.000

TABLE XXIV: Varnode recovery (metatype = INT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sha512sum	301		0	0	0	0	301	1.000	1.000
shred	238		0	0	0	0	238	1.000	1.000
shuf	210		0	0	0	0	210	1.000	1.000
sleep	76		0	0	0	0	76	1.000	1.000
sort	440		0	1	0	0	439	0.998	1.000
split	195		0	0	0	0	195	1.000	1.000
stat	392		0	0	0	0	392	1.000	1.000
stdbuf	156		0	0	0	0	156	1.000	1.000
stty	189		0	0	0	0	189	1.000	1.000
sum	183		0	0	0	0	183	1.000	1.000
sync	83		0	0	0	0	83	1.000	1.000
tac	584		0	1	0	0	583	0.999	1.000
tail	239		0	0	0	0	239	1.000	1.000
tee	95		0	0	0	0	95	1.000	1.000
test	155		0	0	0	0	155	1.000	1.000
timeout	95		0	0	0	0	95	1.000	1.000
touch	396		0	5	0	0	391	0.991	1.000
tr	153		0	0	0	0	153	1.000	1.000
true	62		0	0	0	0	62	1.000	1.000
truncate	91		0	0	0	0	91	1.000	1.000
tsort	85		0	0	0	0	85	1.000	1.000
tty	65		0	0	0	0	65	1.000	1.000
uname	67		0	0	0	0	67	1.000	1.000
unexpand	101		0	0	0	0	101	1.000	1.000
uniq	125		0	0	0	0	125	1.000	1.000
unlink	66		0	0	0	0	66	1.000	1.000
uptime	261		0	0	0	0	261	1.000	1.000
users	73		0	0	0	0	73	1.000	1.000
vdir	615		0	1	0	0	614	0.999	1.000
wc	148		0	0	0	0	148	1.000	1.000
who	158		0	0	0	0	158	1.000	1.000
whoami	68		0	0	0	0	68	1.000	1.000
yes	76		0	0	0	0	76	1.000	1.000

TABLE XXV: Varnode recovery (metatype = FLOAT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	2		0	0	0	0	2	1.000	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	3		0	0	0	0	3	1.000	1.000
chgrp	3		0	0	0	0	3	1.000	1.000
chmod	3		0	0	0	0	3	1.000	1.000
chown	3		0	0	0	0	3	1.000	1.000
chroot	0		0	0	0	0	0	-	-
cksum	3		0	0	0	0	3	1.000	1.000
comm	0		0	0	0	0	0	-	-

TABLE XXV: Varnode recovery (metatype = FLOAT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
cp	3		0	0	0	0	3	1.000	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	0	0	0	2	1.000	1.000
dd	7		0	0	0	0	7	1.000	1.000
df	13		0	0	0	0	13	1.000	1.000
dir	6		0	0	0	0	6	1.000	1.000
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	6		0	0	0	0	6	1.000	1.000
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	3		0	0	0	0	3	1.000	1.000
logname	0		0	0	0	0	0	-	-
ls	6		0	0	0	0	6	1.000	1.000
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	0	0	0	2	1.000	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	3		0	0	0	0	3	1.000	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	0	0	0	7	1.000	1.000
od	11		0	0	0	0	11	1.000	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	0	0	0	7	1.000	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	3		0	0	0	0	3	1.000	1.000
realpath	3		0	0	0	0	3	1.000	1.000
rm	3		0	0	0	0	3	1.000	1.000
rmdir	2		0	0	0	0	2	1.000	1.000
runcon	0		0	0	0	0	0	-	-
seq	10		0	0	0	0	10	1.000	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-

TABLE XXV: Varnode recovery (metatype = FLOAT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	0	0	0	3	1.000	1.000
shuf	3		0	0	0	0	3	1.000	1.000
sleep	7		0	0	0	0	7	1.000	1.000
sort	18		0	0	0	0	18	1.000	1.000
split	0		0	0	0	0	0	-	-
stat	2		0	0	0	0	2	1.000	1.000
stdbuf	2		0	0	0	0	2	1.000	1.000
stty	2		0	0	0	0	2	1.000	1.000
sum	3		0	0	0	0	3	1.000	1.000
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	11		0	0	0	0	11	1.000	1.000
tee	0		0	0	0	0	0	-	-
test	2		0	0	0	0	2	1.000	1.000
timeout	8		0	0	0	0	8	1.000	1.000
touch	2		0	0	0	0	2	1.000	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	2		0	0	0	0	2	1.000	1.000
users	0		0	0	0	0	0	-	-
vdir	6		0	0	0	0	6	1.000	1.000
wc	4		0	0	0	0	4	1.000	1.000
who	2		0	0	0	0	2	1.000	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XXVI: Varnode recovery (metatype = POINTER) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	68		0	0	0	0	68	1.000	1.000
b2sum	56		0	0	0	0	56	1.000	1.000
base32	41		0	0	0	0	41	1.000	1.000
base64	41		0	0	0	0	41	1.000	1.000
basename	38		0	0	0	0	38	1.000	1.000
basenc	55		0	0	0	0	55	1.000	1.000
cat	41		0	0	0	0	41	1.000	1.000
chcon	134		0	0	0	0	134	1.000	1.000
chgrp	133		0	0	0	0	133	1.000	1.000
chmod	127		0	0	0	0	127	1.000	1.000
chown	142		0	0	0	0	142	1.000	1.000
chroot	67		0	0	0	0	67	1.000	1.000

TABLE XXVI: Varnode recovery (metatype = POINTER) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
cksum	99		0	0	0	0	99	1.000	1.000
comm	35		0	0	0	0	35	1.000	1.000
cp	231		0	0	0	0	231	1.000	1.000
csplit	272		0	0	0	0	272	1.000	1.000
cut	46		0	0	0	0	46	1.000	1.000
date	125		0	0	0	0	125	1.000	1.000
dd	98		0	0	0	0	98	1.000	1.000
df	239		0	0	0	0	239	1.000	1.000
dir	293		0	0	0	0	293	1.000	1.000
dircolors	76		0	0	0	0	76	1.000	1.000
dirname	32		0	0	0	0	32	1.000	1.000
du	438		0	0	0	0	438	1.000	1.000
echo	30		0	0	0	0	30	1.000	1.000
env	54		0	0	0	0	54	1.000	1.000
expand	35		0	0	0	0	35	1.000	1.000
expr	259		0	0	0	0	259	1.000	1.000
factor	98		3	0	0	0	95	0.969	0.969
false	28		0	0	0	0	28	1.000	1.000
fmt	52		0	0	0	0	52	1.000	1.000
fold	33		0	0	0	0	33	1.000	1.000
groups	40		0	0	0	0	40	1.000	1.000
head	47		0	0	0	0	47	1.000	1.000
hostid	29		0	0	0	0	29	1.000	1.000
id	60		0	0	0	0	60	1.000	1.000
join	66		0	0	0	0	66	1.000	1.000
kill	36		0	0	0	0	36	1.000	1.000
link	29		0	0	0	0	29	1.000	1.000
ln	161		0	0	0	0	161	1.000	1.000
logname	30		0	0	0	0	30	1.000	1.000
ls	293		0	0	0	0	293	1.000	1.000
md5sum	50		0	0	0	0	50	1.000	1.000
mkdir	71		0	0	0	0	71	1.000	1.000
mkfifo	36		0	0	0	0	36	1.000	1.000
mknod	41		0	0	0	0	41	1.000	1.000
mktemp	44		0	0	0	0	44	1.000	1.000
mv	254		0	0	0	0	254	1.000	1.000
nice	33		0	0	0	0	33	1.000	1.000
nl	247		0	0	0	0	247	1.000	1.000
nohup	40		0	0	0	0	40	1.000	1.000
nproc	32		0	0	0	0	32	1.000	1.000
numfmt	70		0	0	0	0	70	1.000	1.000
od	93		0	0	0	0	93	1.000	1.000
paste	37		0	0	0	0	37	1.000	1.000
pathchk	33		0	0	0	0	33	1.000	1.000
pinky	57		0	0	0	0	57	1.000	1.000
pr	102		0	0	0	0	102	1.000	1.000
printenv	31		0	0	0	0	31	1.000	1.000
printf	76		0	0	0	0	76	1.000	1.000
ptx	331		0	0	0	0	331	1.000	1.000
pwd	41		0	0	0	0	41	1.000	1.000
readlink	100		0	0	0	0	100	1.000	1.000
realpath	105		0	0	0	0	105	1.000	1.000
rm	136		0	0	0	0	136	1.000	1.000
rmdir	66		0	0	0	0	66	1.000	1.000
runcon	36		0	0	0	0	36	1.000	1.000
seq	81		0	0	0	0	81	1.000	1.000

TABLE XXVI: Varnode recovery (metatype = POINTER) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
sha1sum	49		0	0	0	0	49	1.000	1.000
sha224sum	50		0	0	0	0	50	1.000	1.000
sha256sum	50		0	0	0	0	50	1.000	1.000
sha384sum	50		0	0	0	0	50	1.000	1.000
sha512sum	50		0	0	0	0	50	1.000	1.000
shred	87		0	0	0	0	87	1.000	1.000
shuf	134		0	0	0	0	134	1.000	1.000
sleep	35		0	0	0	0	35	1.000	1.000
sort	299		0	0	0	0	299	1.000	1.000
split	69		0	0	0	0	69	1.000	1.000
stat	150		0	0	0	0	150	1.000	1.000
stdbuf	79		0	0	0	0	79	1.000	1.000
stty	73		0	0	0	0	73	1.000	1.000
sum	60		0	0	0	0	60	1.000	1.000
sync	29		0	0	0	0	29	1.000	1.000
tac	250		0	0	0	0	250	1.000	1.000
tail	124		0	0	0	0	124	1.000	1.000
tee	35		0	0	0	0	35	1.000	1.000
test	67		0	0	0	0	67	1.000	1.000
timeout	41		0	0	0	0	41	1.000	1.000
touch	110		0	0	0	0	110	1.000	1.000
tr	58		0	0	0	0	58	1.000	1.000
true	28		0	0	0	0	28	1.000	1.000
truncate	32		0	0	0	0	32	1.000	1.000
tsort	52		0	0	0	0	52	1.000	1.000
tty	29		0	0	0	0	29	1.000	1.000
uname	30		0	0	0	0	30	1.000	1.000
unexpand	36		0	0	0	0	36	1.000	1.000
uniq	50		0	0	0	0	50	1.000	1.000
unlink	29		0	0	0	0	29	1.000	1.000
uptime	57		0	0	0	1	56	0.996	1.000
users	38		0	0	0	0	38	1.000	1.000
vdir	293		0	0	0	0	293	1.000	1.000
wc	84		0	0	0	0	84	1.000	1.000
who	83		0	0	0	0	83	1.000	1.000
whoami	30		0	0	0	0	30	1.000	1.000
yes	34		0	0	0	0	34	1.000	1.000

TABLE XXVII: Varnode recovery (metatype = ARRAY) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	15		0	0	0	0	15	1.000	1.000
b2sum	24		0	0	0	0	24	1.000	1.000
base32	12		0	0	0	0	12	1.000	1.000
base64	12		0	0	0	0	12	1.000	1.000
basename	10		0	0	0	0	10	1.000	1.000
basenc	20		0	0	0	0	20	1.000	1.000
cat	11		0	0	0	0	11	1.000	1.000
chcon	18		0	0	0	0	18	1.000	1.000
chgrp	15		0	0	0	0	15	1.000	1.000



TABLE XXVII: Varnode recovery (metatype = ARRAY) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
chmod	19		0	0	0	0	19	1.000	1.000
chown	16		0	0	0	0	16	1.000	1.000
chroot	11		0	0	0	0	11	1.000	1.000
cksum	66		0	0	0	0	66	1.000	1.000
comm	22		0	0	0	0	22	1.000	1.000
cp	40		0	1	0	0	39	0.981	1.000
csplit	35		0	0	1	0	34	0.986	1.000
cut	12		0	0	0	0	12	1.000	1.000
date	63		0	2	2	0	59	0.960	1.000
dd	34		0	0	0	0	34	1.000	1.000
df	25		0	1	0	0	24	0.970	1.000
dir	71		0	2	3	0	66	0.958	1.000
dircolors	13		0	0	0	0	13	1.000	1.000
dirname	10		0	0	0	0	10	1.000	1.000
du	51		0	0	2	0	49	0.980	1.000
echo	9		0	0	0	0	9	1.000	1.000
env	18		0	0	0	0	18	1.000	1.000
expand	13		0	0	0	0	13	1.000	1.000
expr	33		0	0	1	0	32	0.985	1.000
factor	37		5	0	0	0	32	0.865	0.865
false	9		0	0	0	0	9	1.000	1.000
fmt	12		0	0	0	0	12	1.000	1.000
fold	12		0	0	0	0	12	1.000	1.000
groups	11		0	0	0	0	11	1.000	1.000
head	18		0	0	0	0	18	1.000	1.000
hostid	12		0	0	0	0	12	1.000	1.000
id	14		0	0	0	0	14	1.000	1.000
join	18		0	0	0	0	18	1.000	1.000
kill	14		0	0	0	0	14	1.000	1.000
link	12		0	0	0	0	12	1.000	1.000
ln	22		0	0	0	0	22	1.000	1.000
logname	12		0	0	0	0	12	1.000	1.000
ls	71		0	2	3	0	66	0.958	1.000
md5sum	16		0	0	0	0	16	1.000	1.000
mkdir	19		0	1	0	0	18	0.961	1.000
mkfifo	12		0	0	0	0	12	1.000	1.000
mknod	12		0	0	0	0	12	1.000	1.000
mktemp	12		0	0	0	0	12	1.000	1.000
mv	34		0	1	0	0	33	0.978	1.000
nice	10		0	0	0	0	10	1.000	1.000
nl	36		0	0	1	0	35	0.986	1.000
nohup	13		0	0	0	0	13	1.000	1.000
nproc	10		0	0	0	0	10	1.000	1.000
numfmt	20		0	0	0	0	20	1.000	1.000
od	40		0	0	0	0	40	1.000	1.000
paste	10		0	0	0	0	10	1.000	1.000
pathchk	10		0	0	0	0	10	1.000	1.000
pinky	17		0	0	1	0	16	0.971	1.000
pr	20		0	0	1	0	19	0.975	1.000
printenv	10		0	0	0	0	10	1.000	1.000
printf	17		0	0	0	0	17	1.000	1.000
ptx	39		0	0	1	0	38	0.987	1.000
pwd	10		0	0	0	0	10	1.000	1.000
readlink	12		0	0	0	0	12	1.000	1.000
realpath	11		0	0	0	0	11	1.000	1.000
rm	15		0	0	0	0	15	1.000	1.000
rmdir	14		0	0	0	0	14	1.000	1.000

TABLE XXVII: Varnode recovery (metatype = ARRAY) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
runcon	10		0	0	0	0	10	1.000	1.000
seq	15		0	0	0	0	15	1.000	1.000
sha1sum	16		0	0	0	0	16	1.000	1.000
sha224sum	17		0	0	0	0	17	1.000	1.000
sha256sum	17		0	0	0	0	17	1.000	1.000
sha384sum	17		0	0	0	0	17	1.000	1.000
sha512sum	17		0	0	0	0	17	1.000	1.000
shred	27		0	0	1	0	26	0.981	1.000
shuf	12		0	0	0	0	12	1.000	1.000
sleep	12		0	0	0	0	12	1.000	1.000
sort	46		0	1	0	0	45	0.984	1.000
split	18		0	1	0	0	17	0.958	1.000
stat	32		0	0	1	0	31	0.984	1.000
stdbuf	16		0	0	0	0	16	1.000	1.000
stty	19		0	0	0	0	19	1.000	1.000
sum	22		0	0	0	0	22	1.000	1.000
sync	11		0	0	0	0	11	1.000	1.000
tac	33		0	0	1	0	32	0.985	1.000
tail	20		0	1	0	0	19	0.963	1.000
tee	14		0	0	0	0	14	1.000	1.000
test	12		0	0	0	0	12	1.000	1.000
timeout	13		0	0	0	0	13	1.000	1.000
touch	56		0	2	1	0	53	0.964	1.000
tr	17		0	0	0	0	17	1.000	1.000
true	9		0	0	0	0	9	1.000	1.000
truncate	10		0	0	0	0	10	1.000	1.000
tsort	13		0	0	0	0	13	1.000	1.000
tty	10		0	0	0	0	10	1.000	1.000
uname	12		0	0	0	0	12	1.000	1.000
unexpand	11		0	0	0	0	11	1.000	1.000
uniq	15		0	0	0	0	15	1.000	1.000
unlink	12		0	0	0	0	12	1.000	1.000
uptime	18		0	0	1	0	17	0.972	1.000
users	12		0	0	0	0	12	1.000	1.000
vdir	71		0	2	3	0	66	0.958	1.000
wc	16		0	0	0	0	16	1.000	1.000
who	25		0	0	0	0	25	1.000	1.000
whoami	12		0	0	0	0	12	1.000	1.000
yes	12		0	0	0	0	12	1.000	1.000

TABLE XXVIII: Varnode recovery (metatype = STRUCT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	24		0	0	0	0	24	1.000	1.000
b2sum	10		0	0	0	0	10	1.000	1.000
base32	11		0	0	0	0	11	1.000	1.000
base64	11		0	0	0	0	11	1.000	1.000
basename	10		0	0	0	0	10	1.000	1.000
basenc	11		0	0	0	0	11	1.000	1.000
cat	11		0	0	0	0	11	1.000	1.000

TABLE XXVIII: Varnode recovery (metatype = STRUCT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
chcon	23		0	0	0	0	23	1.000	1.000
chgrp	22		0	0	0	0	22	1.000	1.000
chmod	22		0	0	0	0	22	1.000	1.000
chown	22		0	0	0	0	22	1.000	1.000
chroot	10		0	0	0	0	10	1.000	1.000
cksum	22		0	0	0	0	22	1.000	1.000
comm	10		0	0	0	0	10	1.000	1.000
cp	46		0	0	0	0	46	1.000	1.000
csplit	56		0	0	0	0	56	1.000	1.000
cut	10		0	0	0	0	10	1.000	1.000
date	39		0	1	0	0	38	0.981	1.000
dd	22		0	0	0	0	22	1.000	1.000
df	37		0	1	0	0	36	0.980	1.000
dir	46		0	1	0	0	45	0.984	1.000
dircolors	11		0	0	0	0	11	1.000	1.000
dirname	10		0	0	0	0	10	1.000	1.000
du	73		0	0	0	0	73	1.000	1.000
echo	10		0	0	0	0	10	1.000	1.000
env	17		0	0	0	0	17	1.000	1.000
expand	10		0	0	0	0	10	1.000	1.000
expr	59		0	0	0	0	59	1.000	1.000
factor	32		2	1	0	0	29	0.914	0.938
false	10		0	0	0	0	10	1.000	1.000
fmt	10		0	0	0	0	10	1.000	1.000
fold	10		0	0	0	0	10	1.000	1.000
groups	10		0	0	0	0	10	1.000	1.000
head	12		0	0	0	0	12	1.000	1.000
hostid	10		0	0	0	0	10	1.000	1.000
id	10		0	0	0	0	10	1.000	1.000
join	14		0	0	0	0	14	1.000	1.000
kill	10		0	0	0	0	10	1.000	1.000
link	10		0	0	0	0	10	1.000	1.000
ln	28		0	0	0	0	28	1.000	1.000
logname	10		0	0	0	0	10	1.000	1.000
ls	46		0	1	0	0	45	0.984	1.000
md5sum	12		0	0	0	0	12	1.000	1.000
mkdir	18		0	0	0	0	18	1.000	1.000
mkfifo	12		0	0	0	0	12	1.000	1.000
mknod	12		0	0	0	0	12	1.000	1.000
mktemp	12		0	0	0	0	12	1.000	1.000
mv	53		0	0	0	0	53	1.000	1.000
nice	10		0	0	0	0	10	1.000	1.000
nl	55		0	0	0	0	55	1.000	1.000
nohup	10		0	0	0	0	10	1.000	1.000
nproc	11		0	0	0	0	11	1.000	1.000
numfmt	10		0	0	0	0	10	1.000	1.000
od	13		0	0	0	0	13	1.000	1.000
paste	10		0	0	0	0	10	1.000	1.000
pathchk	13		0	0	0	0	13	1.000	1.000
pinky	12		0	0	0	0	12	1.000	1.000
pr	22		0	0	0	0	22	1.000	1.000
printenv	10		0	0	0	0	10	1.000	1.000
printf	15		0	0	0	0	15	1.000	1.000
ptx	82		0	1	0	0	81	0.991	1.000
pwd	17		0	0	0	0	17	1.000	1.000
readlink	17		0	0	0	0	17	1.000	1.000

TABLE XXVIII: Varnode recovery (metatype = STRUCT) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
realpath	18		0	0	0	0	18	1.000	1.000
rm	23		0	0	0	0	23	1.000	1.000
rmdir	13		0	0	0	0	13	1.000	1.000
runcon	10		0	0	0	0	10	1.000	1.000
seq	17		0	0	0	0	17	1.000	1.000
sha1sum	12		0	0	0	0	12	1.000	1.000
sha224sum	13		0	0	0	0	13	1.000	1.000
sha256sum	13		0	0	0	0	13	1.000	1.000
sha384sum	13		0	0	0	0	13	1.000	1.000
sha512sum	13		0	0	0	0	13	1.000	1.000
shred	15		0	0	0	0	15	1.000	1.000
shuf	15		0	0	0	0	15	1.000	1.000
sleep	13		0	0	0	0	13	1.000	1.000
sort	44		0	0	0	0	44	1.000	1.000
split	15		0	0	0	0	15	1.000	1.000
stat	32		0	0	0	0	32	1.000	1.000
stdbuf	14		0	0	0	0	14	1.000	1.000
stty	18		0	0	0	0	18	1.000	1.000
sum	10		0	0	0	0	10	1.000	1.000
sync	10		0	0	0	0	10	1.000	1.000
tac	53		0	0	0	0	53	1.000	1.000
tail	29		0	0	0	0	29	1.000	1.000
tee	10		0	0	0	0	10	1.000	1.000
test	24		0	0	0	0	24	1.000	1.000
timeout	18		0	0	0	0	18	1.000	1.000
touch	36		0	1	0	0	35	0.979	1.000
tr	13		0	0	0	0	13	1.000	1.000
true	10		0	0	0	0	10	1.000	1.000
truncate	12		0	0	0	0	12	1.000	1.000
tsort	12		0	0	0	0	12	1.000	1.000
tty	10		0	0	0	0	10	1.000	1.000
uname	11		0	0	0	0	11	1.000	1.000
unexpand	10		0	0	0	0	10	1.000	1.000
uniq	12		0	0	0	0	12	1.000	1.000
unlink	10		0	0	0	0	10	1.000	1.000
uptime	15		0	0	0	0	15	1.000	1.000
users	10		0	0	0	0	10	1.000	1.000
vdir	46		0	1	0	0	45	0.984	1.000
wc	16		0	0	0	0	16	1.000	1.000
who	14		0	0	0	0	14	1.000	1.000
whoami	10		0	0	0	0	10	1.000	1.000
yes	10		0	0	0	0	10	1.000	1.000

TABLE XXIX: Varnode recovery (metatype = UNION) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	0		0	0	0	0	0	-	-
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-

TABLE XXIX: Varnode recovery (metatype = UNION) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	0		0	0	0	0	0	-	-
chgrp	0		0	0	0	0	0	-	-
chmod	0		0	0	0	0	0	-	-
chown	0		0	0	0	0	0	-	-
chroot	0		0	0	0	0	0	-	-
cksum	0		0	0	0	0	0	-	-
comm	0		0	0	0	0	0	-	-
cp	1		0	0	0	0	1	1.000	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	0	0	0	2	1.000	1.000
dd	0		0	0	0	0	0	-	-
df	0		0	0	0	0	0	-	-
dir	0		0	0	0	0	0	-	-
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	0		0	0	0	0	0	-	-
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	1		0	0	0	0	1	1.000	1.000
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	0		0	0	0	0	0	-	-
logname	0		0	0	0	0	0	-	-
ls	0		0	0	0	0	0	-	-
md5sum	0		0	0	0	0	0	-	-
mkdir	0		0	0	0	0	0	-	-
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	1		0	0	0	0	1	1.000	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	0		0	0	0	0	0	-	-
od	8		0	0	0	0	8	1.000	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	0		0	0	0	0	0	-	-
ptx	1		0	0	0	0	1	1.000	1.000

TABLE XXIX: Varnode recovery (metatype = UNION) (compilation = debug)

	Ground varnodes	truth	Decompiler varnodes matched @ level NO_MATCH	Decompiler varnodes matched @ level OVERLAP	Decompiler varnodes matched @ level SUBSET	Decompiler varnodes matched @ level ALIGNED	Decompiler varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
pwd	0		0	0	0	0	0	-	-
readlink	0		0	0	0	0	0	-	-
realpath	0		0	0	0	0	0	-	-
rm	0		0	0	0	0	0	-	-
rmdir	0		0	0	0	0	0	-	-
runcon	0		0	0	0	0	0	-	-
seq	0		0	0	0	0	0	-	-
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	0		0	0	0	0	0	-	-
shuf	0		0	0	0	0	0	-	-
sleep	0		0	0	0	0	0	-	-
sort	0		0	0	0	0	0	-	-
split	0		0	0	0	0	0	-	-
stat	0		0	0	0	0	0	-	-
stdbuf	0		0	0	0	0	0	-	-
stty	0		0	0	0	0	0	-	-
sum	0		0	0	0	0	0	-	-
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	0		0	0	0	0	0	-	-
tee	0		0	0	0	0	0	-	-
test	0		0	0	0	0	0	-	-
timeout	0		0	0	0	0	0	-	-
touch	2		0	0	0	2	0	0.750	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	0		0	0	0	0	0	-	-
users	0		0	0	0	0	0	-	-
vdir	0		0	0	0	0	0	-	-
wc	0		0	0	0	0	0	-	-
who	0		0	0	0	0	0	-	-
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XXX: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode fraction partial recovery
[	1190		391	129	0	233	437	0.541	0.671
b2sum	1954		607	174	0	775	398	0.523	0.689
base32	1169		647	82	0	102	338	0.372	0.447
base64	1197		679	78	0	102	338	0.363	0.433

TABLE XXX: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode frac- tion partial recovery
basename	844		359	74	0	98	313	0.480	0.575
basenc	1847		1276	76	0	128	367	0.261	0.309
cat	933		394	78	0	129	332	0.480	0.578
chcon	17348		436	79	0	16395	438	0.735	0.975
chgrp	1264		463	83	0	291	427	0.527	0.634
chmod	1305		493	85	0	292	435	0.517	0.622
chown	1308		466	82	0	320	440	0.536	0.644
chroot	933		359	75	0	129	370	0.520	0.615
cksum	31618		11527	17077	0	2434	580	0.211	0.635
comm	998		367	98	0	202	331	0.508	0.632
cp	4028		1852	249	0	474	1453	0.464	0.540
csplit	5511		819	455	0	1885	2352	0.704	0.851
cut	5022		381	74	0	4232	335	0.702	0.924
date	8648		2437	238	0	2928	3045	0.613	0.718
dd	6329		1987	128	0	2993	1221	0.553	0.686
df	3575		514	189	0	1764	1108	0.693	0.856
dir	39259		9090	178	0	16150	13841	0.662	0.768
dircolors	5810		5258	77	0	140	335	0.079	0.095
dirname	832		352	74	0	94	312	0.482	0.577
du	8012		1042	558	0	2843	3569	0.729	0.870
echo	810		335	74	0	92	309	0.490	0.586
env	1464		751	74	0	218	421	0.412	0.487
expand	898		390	74	0	113	321	0.472	0.566
expr	5706		930	472	0	2017	2287	0.687	0.837
factor	4701		3420	335	0	263	683	0.205	0.272
false	801		335	74	0	87	305	0.485	0.582
fmt	15915		15374	74	0	132	335	0.028	0.034
fold	893		394	74	0	101	324	0.468	0.559
groups	865		368	74	0	101	322	0.481	0.575
head	33790		392	97	0	24757	8544	0.803	0.988
hostid	827		347	74	0	97	309	0.484	0.580
id	1007		438	74	0	144	351	0.474	0.565
join	1004		381	76	0	178	369	0.519	0.621
kill	1325		787	74	0	119	345	0.342	0.406
link	826		347	74	0	96	309	0.484	0.580
ln	1991		604	142	0	263	982	0.610	0.697
logname	827		347	74	0	97	309	0.484	0.580
ls	39259		9090	178	0	16150	13841	0.662	0.768
md5sum	1170		467	154	0	199	350	0.460	0.601
mkdir	3260		449	118	0	2208	485	0.666	0.862
mkfifo	938		404	80	0	108	346	0.477	0.569
mknod	955		404	80	0	111	360	0.485	0.577
mktemp	971		432	94	0	115	330	0.453	0.555
mv	4056		1781	270	0	538	1467	0.478	0.561
nice	837		351	74	0	94	318	0.486	0.581
nl	6094		1656	453	0	1721	2264	0.602	0.728
nohup	874		347	74	0	134	319	0.501	0.603
nproc	865		355	76	0	96	338	0.496	0.590
numfmt	1280		447	142	0	163	528	0.536	0.651
od	11965		698	117	0	10606	544	0.713	0.942
paste	857		359	74	0	106	318	0.485	0.581
pathchk	869		353	96	0	107	313	0.480	0.594
pinky	3335		425	81	0	2212	617	0.689	0.873
pr	2854		529	138	0	397	1790	0.744	0.815
printenv	826		351	74	0	89	312	0.481	0.575
printf	3369		518	120	0	2194	537	0.657	0.846
ptx	7315		2390	623	0	1869	2433	0.546	0.673
pwd	969		445	80	0	109	335	0.451	0.541

TABLE XXX: Decomposed varnode recovery (compilation = stripped)

	Ground vsnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partially recovered
readlink	1146		386	99	0	162	499	0.563	0.663
realpath	1051		410	102	0	163	376	0.498	0.610
rm	1276		457	121	0	268	430	0.518	0.642
rmdir	3076		386	107	0	2161	422	0.673	0.875
runcon	844		367	74	0	96	307	0.471	0.565
seq	1136		396	121	0	174	445	0.533	0.651
sha1sum	1178		467	158	0	185	368	0.464	0.604
sha224sum	1315		531	205	0	206	373	0.440	0.596
sha256sum	1323		531	205	0	214	373	0.442	0.599
sha384sum	1599		611	205	0	410	373	0.458	0.618
sha512sum	1631		611	205	0	442	373	0.463	0.625
shred	3337		562	90	0	1614	1071	0.690	0.832
shuf	1168		406	90	0	243	429	0.543	0.652
sleep	855		347	76	0	107	325	0.496	0.594
sort	11845		2147	336	0	686	8676	0.783	0.819
split	1533		780	80	0	242	431	0.413	0.491
stat	3141		741	189	0	416	1795	0.686	0.764
stdbuf	2142		375	124	0	1200	443	0.641	0.825
stty	1868		1102	108	0	197	461	0.340	0.410
sum	2368		382	79	0	1518	389	0.653	0.839
sync	847		355	74	0	106	312	0.484	0.581
tac	13723		9252	453	0	1756	2262	0.269	0.326
tail	34216		566	120	0	33048	482	0.739	0.983
tee	9070		367	74	0	8310	319	0.724	0.960
test	1126		344	129	0	221	432	0.560	0.694
timeout	1334		682	76	0	130	446	0.422	0.489
touch	7107		2125	214	0	2824	1944	0.579	0.701
tr	10204		9337	345	0	143	379	0.056	0.085
true	801		335	74	0	87	305	0.485	0.582
truncate	902		384	90	0	104	324	0.471	0.574
tsort	876		347	83	0	120	326	0.499	0.604
tty	825		355	76	0	88	306	0.474	0.570
uname	1274		410	74	0	92	698	0.617	0.678
unexpand	874		360	74	0	113	327	0.492	0.588
uniq	962		401	77	0	138	346	0.487	0.583
unlink	826		347	74	0	96	309	0.484	0.580
uptime	10379		380	109	0	256	9634	0.949	0.963
users	842		347	74	0	106	315	0.490	0.588
vdir	39259		9090	178	0	16150	13841	0.662	0.768
wc	33888		444	75	0	32916	453	0.742	0.987
who	1577		472	119	0	221	765	0.609	0.701
whoami	829		347	74	0	99	309	0.485	0.581
yes	841		347	74	0	105	315	0.490	0.587

TABLE XXXI: Decomposed varnode recovery (compilation = stripped)

	Ground vsnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	1010		379	116	0	171	344	0.496	0.625
b2sum	1813		567	169	0	719	358	0.518	0.687
base32	1061		623	77	0	56	305	0.345	0.413
base64	1089		655	73	0	56	305	0.335	0.399
basename	739		335	69	0	52	283	0.459	0.547
basenc	1707		1236	70	0	75	326	0.234	0.276



TABLE XXXI: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
cat	817		362	73	0	82	300	0.465	0.557
chcon	17106		390	70	0	16271	375	0.736	0.977
chgrp	1026		418	78	0	168	362	0.495	0.593
chmod	1080		453	80	0	172	375	0.485	0.581
chown	1059		420	77	0	192	370	0.504	0.603
chroot	799		335	70	0	79	315	0.490	0.581
cksum	31380		11445	17069	0	2354	512	0.209	0.635
comm	870		339	85	0	146	300	0.495	0.610
cp	3616		1744	244	0	304	1324	0.446	0.518
csplit	4073		774	181	0	857	2261	0.724	0.810
cut	4899		347	69	0	4181	302	0.705	0.929
date	8190		2255	202	0	2841	2892	0.619	0.725
dd	6097		1967	112	0	2915	1103	0.544	0.677
df	3126		437	170	0	1620	899	0.690	0.860
dir	38591		8808	167	0	15943	13673	0.665	0.772
dircolors	5577		5150	72	0	64	291	0.064	0.077
dirname	737		332	69	0	51	285	0.462	0.550
du	6328		947	277	0	1709	3395	0.750	0.850
echo	725		323	69	0	50	283	0.466	0.554
env	1323		713	69	0	162	379	0.391	0.461
expand	796		367	69	0	66	294	0.453	0.539
expr	4280		901	192	0	991	2196	0.698	0.789
factor	4491		3399	305	0	174	613	0.183	0.243
false	718		323	69	0	45	281	0.462	0.550
fmt	13788		13343	69	0	77	299	0.027	0.032
fold	793		370	69	0	58	296	0.450	0.533
groups	764		350	69	0	56	289	0.456	0.542
head	33664		359	92	0	24705	8508	0.804	0.989
hostid	733		329	69	0	54	281	0.462	0.551
id	872		406	69	0	95	302	0.448	0.534
join	854		347	71	0	113	323	0.498	0.594
kill	1222		763	69	0	76	314	0.318	0.376
link	732		329	69	0	53	281	0.462	0.551
ln	1704		544	135	0	138	887	0.601	0.681
logname	732		329	69	0	53	281	0.462	0.551
ls	38591		8808	167	0	15943	13673	0.665	0.772
md5sum	1037		429	149	0	142	317	0.444	0.586
mkdir	3057		423	104	0	2140	390	0.661	0.862
mkfifo	837		382	75	0	59	321	0.459	0.544
mknod	849		382	75	0	60	332	0.466	0.550
mktemp	853		402	89	0	65	297	0.431	0.529
mv	3668		1719	264	0	323	1362	0.455	0.531
nice	741		331	69	0	52	289	0.466	0.553
nl	4669		1596	179	0	722	2172	0.591	0.658
nohup	767		329	69	0	82	287	0.477	0.571
nproc	768		333	71	0	54	310	0.479	0.566
numfmt	1088		379	131	0	104	474	0.537	0.652
od	11712		659	100	0	10534	419	0.712	0.944
paste	753		335	69	0	60	289	0.466	0.555
pathchk	771		332	90	0	62	287	0.462	0.569
pinky	3214		404	76	0	2152	582	0.689	0.874
pr	2634		461	133	0	308	1732	0.758	0.825
printenv	732		331	69	0	47	285	0.461	0.548
printf	3173		505	98	0	2131	439	0.650	0.841
ptx	5741		2318	337	0	803	2283	0.517	0.596
pwd	863		423	75	0	57	308	0.428	0.510
readlink	948		346	92	0	79	431	0.541	0.635
realpath	844		366	95	0	75	308	0.460	0.566

TABLE XXXI: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
rm	1032		409	116	0	140	367	0.485	0.604
rmdir	2886		360	94	0	2103	329	0.669	0.875
runcon	737		339	69	0	47	282	0.454	0.540
seq	921		372	96	0	112	341	0.488	0.596
sha1sum	1046		429	153	0	129	335	0.449	0.590
sha224sum	1182		493	200	0	149	340	0.424	0.583
sha256sum	1190		493	200	0	157	340	0.427	0.586
sha384sum	1466		573	200	0	353	340	0.447	0.609
sha512sum	1498		573	200	0	385	340	0.453	0.617
shred	3159		523	82	0	1532	1022	0.694	0.834
shuf	942		370	84	0	137	351	0.504	0.607
sleep	748		329	71	0	60	288	0.469	0.560
sort	11317		2020	320	0	452	8525	0.790	0.822
split	1369		734	74	0	176	385	0.391	0.464
stat	2845		707	174	0	312	1652	0.678	0.751
stdbuf	1931		348	111	0	1134	338	0.630	0.820
stty	1527		937	95	0	133	362	0.318	0.386
sum	2233		358	71	0	1461	343	0.652	0.840
sync	751		333	69	0	61	288	0.467	0.557
tac	12312		9213	179	0	744	2176	0.226	0.252
tail	33975		516	113	0	32951	395	0.740	0.985
tee	8961		339	69	0	8261	292	0.726	0.962
test	959		332	116	0	169	342	0.519	0.654
timeout	1210		654	71	0	81	404	0.399	0.460
touch	6684		1960	179	0	2744	1801	0.584	0.707
tr	10057		9300	332	0	82	343	0.048	0.075
true	718		323	69	0	45	281	0.462	0.550
truncate	801		358	85	0	60	298	0.455	0.553
tsort	757		329	77	0	62	289	0.469	0.565
tty	731		333	71	0	46	281	0.456	0.544
uname	1155		365	69	0	48	673	0.629	0.684
unexpand	769		335	69	0	66	299	0.476	0.564
uniq	818		356	72	0	84	306	0.473	0.565
unlink	732		329	69	0	53	281	0.462	0.551
uptime	10247		360	104	0	191	9592	0.953	0.965
users	739		329	69	0	56	285	0.466	0.555
vdir	38591		8808	167	0	15943	13673	0.665	0.772
wc	33696		386	71	0	32838	401	0.743	0.989
who	1345		421	106	0	154	664	0.599	0.687
whoami	734		329	69	0	55	281	0.463	0.552
yes	742		329	69	0	59	285	0.467	0.557

TABLE XXXII: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	2		0	1	0	1	0	0.500	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	7		4	0	0	3	0	0.321	0.429

TABLE XXXII: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
chgrp	7		4	0	0	3	0	0.321	0.429
chmod	7		4	0	0	3	0	0.321	0.429
chown	7		4	0	0	3	0	0.321	0.429
chroot	0		0	0	0	0	0	-	-
cksum	3		0	3	0	0	0	0.250	1.000
comm	0		0	0	0	0	0	-	-
cp	7		4	0	0	3	0	0.321	0.429
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	1	0	1	0	0.500	1.000
dd	7		0	4	0	3	0	0.464	1.000
df	17		4	4	0	4	5	0.529	0.765
dir	10		4	3	0	3	0	0.300	0.600
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	10		4	3	0	3	0	0.300	0.600
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	7		4	0	0	3	0	0.321	0.429
logname	0		0	0	0	0	0	-	-
ls	10		4	3	0	3	0	0.300	0.600
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	1	0	1	0	0.500	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	7		4	0	0	3	0	0.321	0.429
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	6	0	1	0	0.321	1.000
od	11		0	4	0	7	0	0.568	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	6	0	1	0	0.321	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	7		4	0	0	3	0	0.321	0.429
realpath	7		4	0	0	3	0	0.321	0.429
rm	7		4	0	0	3	0	0.321	0.429
rmdir	2		0	1	0	1	0	0.500	1.000

TABLE XXXII: Decomposed varnode recovery (compilation = stripped)

	Ground vsnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
runcon	0		0	0	0	0	0	-	-
seq	14		0	13	0	1	0	0.286	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	3	0	0	0	0.250	1.000
shuf	7		4	0	0	3	0	0.321	0.429
sleep	7		0	0	0	2	5	0.929	1.000
sort	22		4	5	0	11	2	0.523	0.818
split	0		0	0	0	0	0	-	-
stat	2		0	1	0	1	0	0.500	1.000
stdbuf	2		0	1	0	1	0	0.500	1.000
stty	2		0	1	0	1	0	0.500	1.000
sum	3		0	3	0	0	0	0.250	1.000
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	15		4	0	0	6	5	0.633	0.733
tee	0		0	0	0	0	0	-	-
test	2		0	1	0	1	0	0.500	1.000
timeout	8		0	0	0	4	4	0.875	1.000
touch	2		0	1	0	1	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	5		0	0	0	4	1	0.800	1.000
users	0		0	0	0	0	0	-	-
vdir	10		4	3	0	3	0	0.300	0.600
wc	4		0	0	0	4	0	0.750	1.000
who	2		0	1	0	1	0	0.500	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XXXIII: Decomposed varnode recovery (compilation = stripped)

	Ground vsnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	170		12	4	0	61	93	0.822	0.929
b2sum	140		40	4	0	56	40	0.593	0.714
base32	107		24	4	0	46	33	0.640	0.776
base64	107		24	4	0	46	33	0.640	0.776
basename	104		24	4	0	46	30	0.630	0.769
basenc	138		40	4	0	53	41	0.592	0.710
cat	115		32	4	0	47	32	0.593	0.722
chcon	234		42	8	0	121	63	0.666	0.821
chgrp	230		41	4	0	120	65	0.678	0.822
chmod	217		36	4	0	117	60	0.685	0.834

TABLE XXXIII: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
chown	241		42	4	0	125	70	0.684	0.826
chroot	133		24	4	0	50	55	0.703	0.820
cksum	234		82	4	0	80	68	0.551	0.650
comm	127		28	12	0	56	31	0.598	0.780
cp	403		104	4	0	167	128	0.631	0.742
csplit	1416		44	266	0	1023	83	0.647	0.969
cut	122		34	4	0	51	33	0.592	0.721
date	426		182	5	0	86	153	0.513	0.573
dd	216		20	4	0	75	117	0.807	0.907
df	419		71	6	0	140	202	0.736	0.831
dir	642		267	7	0	204	164	0.496	0.584
dircolors	229		105	4	0	76	44	0.445	0.541
dirname	94		20	4	0	43	27	0.641	0.787
du	1650		90	267	0	1126	167	0.653	0.945
echo	84		12	4	0	42	26	0.696	0.857
env	138		38	4	0	56	40	0.601	0.725
expand	101		23	4	0	47	27	0.626	0.772
expr	1399		28	266	0	1021	84	0.655	0.980
factor	196		21	18	0	88	69	0.712	0.893
false	82		12	4	0	42	24	0.689	0.854
fmt	2126		2031	4	0	55	36	0.037	0.045
fold	99		24	4	0	43	28	0.619	0.758
groups	100		18	4	0	45	33	0.677	0.820
head	125		33	4	0	52	36	0.608	0.736
hostid	93		18	4	0	43	28	0.659	0.806
id	134		32	4	0	49	49	0.647	0.761
join	149		34	4	0	65	46	0.643	0.772
kill	102		24	4	0	43	31	0.630	0.765
link	93		18	4	0	43	28	0.659	0.806
ln	276		54	5	0	122	95	0.680	0.804
logname	94		18	4	0	44	28	0.660	0.809
ls	642		267	7	0	204	164	0.496	0.584
md5sum	132		38	4	0	57	33	0.581	0.712
mkdir	192		26	4	0	67	95	0.762	0.865
mkfifo	100		22	4	0	49	25	0.627	0.780
mknod	105		22	4	0	51	28	0.640	0.790
mktemp	117		30	4	0	50	33	0.611	0.744
mv	379		58	5	0	212	104	0.697	0.847
nice	95		20	4	0	42	29	0.647	0.789
nl	1404		59	266	0	994	85	0.639	0.958
nohup	106		18	4	0	52	32	0.679	0.830
nproc	96		22	4	0	42	28	0.630	0.771
numfmt	184		68	4	0	58	54	0.535	0.630
od	226		39	4	0	64	119	0.743	0.827
paste	103		24	4	0	46	29	0.626	0.767
pathchk	95		20	4	0	45	26	0.639	0.789
pinky	120		21	4	0	60	35	0.675	0.825
pr	218		68	5	0	89	56	0.569	0.688
printenv	93		20	4	0	42	27	0.640	0.785
printf	178		13	5	0	62	98	0.819	0.927
ptx	1540		71	266	0	1060	143	0.652	0.954
pwd	105		22	4	0	52	27	0.638	0.790
readlink	187		34	5	0	80	68	0.691	0.818
realpath	196		38	5	0	85	68	0.679	0.806
rm	236		44	4	0	125	63	0.668	0.814
rmdir	180		26	4	0	57	93	0.760	0.856
runcon	106		28	4	0	49	25	0.592	0.736
seq	193		24	4	0	61	104	0.781	0.876

TABLE XXXIII: Decomposed varnode recovery (compilation = stripped)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sha1sum	131		38	4	0	56	33	0.580	0.710
sha224sum	132		38	4	0	57	33	0.581	0.712
sha256sum	132		38	4	0	57	33	0.581	0.712
sha384sum	132		38	4	0	57	33	0.581	0.712
sha512sum	132		38	4	0	57	33	0.581	0.712
shred	174		39	4	0	82	49	0.641	0.776
shuf	218		32	5	0	103	78	0.718	0.853
sleep	99		18	4	0	45	32	0.674	0.818
sort	492		114	9	0	223	146	0.641	0.768
split	162		46	5	0	66	45	0.591	0.716
stat	286		34	6	0	103	143	0.775	0.881
stdbuf	201		27	4	0	65	105	0.770	0.866
stty	331		165	4	0	63	99	0.445	0.502
sum	131		24	4	0	57	46	0.685	0.817
sync	95		22	4	0	45	24	0.618	0.768
tac	1390		38	266	0	1007	79	0.648	0.973
tail	225		46	6	0	91	82	0.674	0.796
tee	108		28	4	0	49	27	0.600	0.741
test	157		12	4	0	51	90	0.823	0.924
timeout	113		28	4	0	45	36	0.626	0.752
touch	391		165	4	0	79	143	0.520	0.578
tr	146		37	12	0	61	36	0.580	0.747
true	82		12	4	0	42	24	0.689	0.854
truncate	100		26	4	0	44	26	0.600	0.740
tsort	118		18	5	0	58	37	0.693	0.847
tty	93		22	4	0	42	25	0.618	0.763
uname	118		45	4	0	44	25	0.500	0.619
unexpand	104		25	4	0	47	28	0.618	0.760
uniq	143		45	4	0	54	40	0.570	0.685
unlink	93		18	4	0	43	28	0.659	0.806
uptime	126		20	4	0	61	41	0.696	0.841
users	102		18	4	0	50	30	0.672	0.824
vdir	642		267	7	0	204	164	0.496	0.584
wc	176		49	4	0	74	49	0.599	0.722
who	222		51	4	0	66	101	0.682	0.770
whoami	94		18	4	0	44	28	0.660	0.809
yes	98		18	4	0	46	30	0.668	0.816

TABLE XXXIV: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partial recovery
[	1190		47	152	0	484	507	0.763	0.961
b2sum	1954		47	277	0	1234	396	0.712	0.976
base32	1169		79	145	0	609	336	0.709	0.932
base64	1197		47	141	0	673	336	0.732	0.961
basename	844		47	137	0	349	311	0.719	0.944
basenc	1847		308	171	0	1003	365	0.628	0.833
cat	933		47	153	0	390	343	0.722	0.950
chcon	17348		49	180	0	16645	474	0.750	0.997
chgrp	1264		50	171	0	539	504	0.752	0.960
chmod	1305		70	163	0	543	529	0.749	0.946
chown	1308		49	175	0	566	518	0.754	0.963
chroot	933		47	138	0	380	368	0.737	0.950

TABLE XXXIV: Decomposed varnode recovery (compilation = standard)

	Ground vartnodes	truth	Vartnodes matched @ level NO_MATCH	Vartnodes matched @ level OVERLAP	Vartnodes matched @ level SUBSET	Vartnodes matched @ level ALIGNED	Vartnodes matched @ level MATCH	Vartnode aver- age comparison score [0,1]	Vartnode frac- tion of partial recovery
cksum	31618		8266	19512	0	3271	569	0.250	0.739
comm	998		47	171	0	451	329	0.711	0.953
cp	4028		205	399	0	1746	1678	0.766	0.949
csplit	5511		455	584	0	2122	2350	0.742	0.917
cut	5022		47	157	0	4485	333	0.744	0.991
date	8648		338	790	0	4470	3050	0.763	0.961
dd	6329		625	208	0	4278	1218	0.708	0.901
df	3575		49	342	0	2002	1182	0.775	0.986
dir	39259		4924	745	0	19731	13859	0.735	0.875
dircolors	5810		4855	238	0	386	331	0.117	0.164
dirname	832		47	129	0	346	310	0.723	0.944
du	8012		514	789	0	3107	3602	0.765	0.936
echo	810		47	113	0	343	307	0.731	0.942
env	1464		362	197	0	486	419	0.569	0.753
expand	898		47	135	0	398	318	0.724	0.948
expr	5706		601	552	0	2268	2285	0.723	0.895
factor	4701		281	1750	0	1989	681	0.555	0.940
false	801		47	113	0	338	303	0.730	0.941
fmt	15915		47	10153	0	5382	333	0.434	0.997
fold	893		47	137	0	387	322	0.724	0.947
groups	865		47	125	0	373	320	0.729	0.946
head	33790		47	155	0	25008	8580	0.810	0.999
hostid	827		47	125	0	348	307	0.725	0.943
id	1007		47	153	0	458	349	0.726	0.953
join	1004		47	166	0	424	367	0.724	0.953
kill	1325		475	137	0	370	343	0.494	0.642
link	826		47	125	0	347	307	0.725	0.943
ln	1991		112	210	0	525	1144	0.799	0.944
logname	827		47	125	0	348	307	0.725	0.943
ls	39259		4924	745	0	19731	13859	0.735	0.875
md5sum	1170		63	245	0	514	348	0.679	0.946
mkdir	3260		64	182	0	2456	558	0.750	0.980
mkfifo	938		64	133	0	358	383	0.730	0.932
mknod	955		64	133	0	361	397	0.734	0.933
mktemp	971		110	148	0	366	347	0.678	0.887
mv	4056		257	296	0	1795	1708	0.771	0.937
nice	837		47	129	0	345	316	0.725	0.944
nl	6094		478	617	0	2737	2262	0.733	0.922
nohup	874		47	125	0	385	317	0.729	0.946
nproc	865		47	133	0	349	336	0.729	0.946
numfmt	1280		47	297	0	414	522	0.708	0.963
od	11965		103	313	0	10991	558	0.742	0.991
paste	857		47	137	0	357	316	0.721	0.945
pathchk	869		47	133	0	358	331	0.728	0.946
pinky	3335		47	137	0	2518	633	0.766	0.986
pr	2854		102	293	0	651	1808	0.830	0.964
printenv	826		47	129	0	340	310	0.723	0.943
printf	3369		222	164	0	2447	536	0.716	0.934
ptx	7315		663	821	0	3383	2448	0.710	0.909
pwd	969		47	142	0	358	422	0.749	0.951
readlink	1146		49	166	0	414	517	0.758	0.957
realpath	1051		49	174	0	415	413	0.730	0.953
rm	1276		66	183	0	517	510	0.739	0.948
rmdir	3076		47	178	0	2412	439	0.745	0.985
runcon	844		47	145	0	347	305	0.713	0.944
seq	1136		47	191	0	458	440	0.732	0.959
sha1sum	1178		63	247	0	502	366	0.683	0.947
sha224sum	1315		63	360	0	521	371	0.648	0.952

TABLE XXXIV: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partially recovered
sha256sum	1323		63	360	0	529	371	0.648	0.952
sha384sum	1599		143	296	0	789	371	0.648	0.911
sha512sum	1631		143	296	0	821	371	0.650	0.912
shred	3337		112	231	0	1871	1123	0.774	0.966
shuf	1168		47	160	0	496	465	0.751	0.960
sleep	855		47	127	0	358	323	0.729	0.945
sort	11845		269	574	0	2293	8709	0.893	0.977
split	1533		379	237	0	490	427	0.557	0.753
stat	3141		225	310	0	785	1821	0.792	0.928
stdbuf	2142		47	187	0	1449	459	0.743	0.978
stty	1868		53	697	0	662	456	0.603	0.972
sum	2368		63	143	0	1778	384	0.740	0.973
sync	847		47	133	0	357	310	0.721	0.945
tac	13723		455	556	0	10453	2259	0.746	0.967
tail	34216		68	203	0	33300	645	0.750	0.998
tee	9070		47	146	0	8561	316	0.747	0.995
test	1126		0	152	0	472	502	0.794	1.000
timeout	1334		362	147	0	381	444	0.575	0.729
touch	7107		313	733	0	4095	1966	0.735	0.956
tr	10204		50	424	0	9354	376	0.735	0.995
true	801		47	113	0	338	303	0.730	0.941
truncate	902		47	141	0	355	359	0.732	0.948
tsort	876		47	132	0	373	324	0.727	0.946
tty	825		47	133	0	341	304	0.719	0.943
uname	1274		55	181	0	343	695	0.783	0.957
unexpand	874		47	139	0	364	324	0.723	0.946
uniq	962		47	184	0	389	342	0.707	0.951
unlink	826		47	125	0	347	307	0.725	0.943
uptime	10379		49	184	0	514	9632	0.970	0.995
users	842		47	125	0	357	313	0.727	0.944
vdir	39259		4924	745	0	19731	13859	0.735	0.875
wc	33888		87	164	0	33168	469	0.749	0.997
who	1577		47	243	0	505	782	0.775	0.970
whoami	829		47	125	0	350	307	0.725	0.943
yes	841		47	125	0	356	313	0.727	0.944

TABLE XXXV: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	1010		47	123	0	424	416	0.757	0.953
b2sum	1813		47	228	0	1180	358	0.717	0.974
base32	1061		79	112	0	565	305	0.713	0.926
base64	1089		47	108	0	629	305	0.738	0.957
basename	739		47	104	0	305	283	0.728	0.936
basenc	1707		308	121	0	952	326	0.627	0.820
cat	817		47	112	0	342	316	0.735	0.942
chcon	17106		47	123	0	16523	413	0.750	0.997
chgrp	1026		47	120	0	418	441	0.765	0.954
chmod	1080		68	116	0	425	471	0.758	0.937
chown	1059		47	122	0	440	450	0.765	0.956
chroot	799		47	105	0	332	315	0.739	0.941
cksum	31380		8266	19409	0	3193	512	0.247	0.737
comm	870		47	126	0	397	300	0.723	0.946



TABLE XXXV: Decomposed varnode recovery (compilation = standard)

	Ground vartnodes	truth	Vartnodes matched @ level NO_MATCH	Vartnodes matched @ level OVERLAP	Vartnodes matched @ level SUBSET	Vartnodes matched @ level ALIGNED	Vartnodes matched @ level MATCH	Vartnode average compare score [0,1]	Vartnode fraction partial recovery
cp	3616		202	280	0	1579	1555	0.777	0.944
csplit	4073		444	272	0	1096	2261	0.774	0.891
cut	4899		47	114	0	4436	302	0.747	0.990
date	8190		333	557	0	4388	2912	0.774	0.959
dd	6097		625	167	0	4202	1103	0.705	0.897
df	3126		47	242	0	1860	977	0.778	0.985
dir	38591		4921	431	0	19529	13710	0.738	0.872
dircolors	5577		4855	115	0	316	291	0.100	0.129
dirname	737		47	100	0	305	285	0.731	0.936
du	6328		500	421	0	1974	3433	0.793	0.921
echo	725		47	92	0	303	283	0.736	0.935
env	1323		362	150	0	432	379	0.560	0.726
expand	796		47	102	0	353	294	0.734	0.941
expr	4280		590	250	0	1244	2196	0.746	0.862
factor	4491		280	1694	0	1904	613	0.549	0.938
false	718		47	92	0	298	281	0.735	0.935
fmt	13788		47	8112	0	5330	299	0.459	0.997
fold	793		47	104	0	346	296	0.733	0.941
groups	764		47	98	0	330	289	0.734	0.938
head	33664		47	112	0	24958	8547	0.811	0.999
hostid	733		47	98	0	307	281	0.731	0.936
id	872		47	112	0	411	302	0.732	0.946
join	854		47	120	0	364	323	0.733	0.945
kill	1222		475	104	0	329	314	0.480	0.611
link	732		47	98	0	306	281	0.731	0.936
ln	1704		110	139	0	402	1053	0.815	0.935
logname	732		47	98	0	306	281	0.731	0.936
ls	38591		4921	431	0	19529	13710	0.738	0.872
md5sum	1037		63	198	0	459	317	0.685	0.939
mkdir	3057		64	138	0	2390	465	0.750	0.979
mkfifo	837		64	102	0	311	360	0.739	0.924
mknod	849		64	102	0	312	371	0.743	0.925
mktemp	853		110	108	0	318	317	0.683	0.871
mv	3668		252	227	0	1585	1604	0.777	0.931
nice	741		47	100	0	305	289	0.732	0.937
nl	4669		467	289	0	1741	2172	0.760	0.900
nohup	767		47	98	0	335	287	0.734	0.939
nproc	768		47	102	0	309	310	0.739	0.939
numfmt	1088		47	210	0	357	474	0.730	0.957
od	11712		103	251	0	10921	437	0.742	0.991
paste	753		47	104	0	313	289	0.730	0.938
pathchk	771		47	102	0	315	307	0.738	0.939
pinky	3214		47	107	0	2460	600	0.769	0.985
pr	2634		101	218	0	563	1752	0.846	0.962
printenv	732		47	100	0	300	285	0.731	0.936
printf	3173		222	126	0	2386	439	0.712	0.930
ptx	5741		652	454	0	2334	2301	0.725	0.886
pwd	863		47	111	0	308	397	0.760	0.946
readlink	948		47	117	0	333	451	0.770	0.950
realpath	844		47	121	0	329	347	0.739	0.944
rm	1032		64	127	0	392	449	0.751	0.938
rmdir	2886		47	135	0	2356	348	0.745	0.984
runcon	737		47	108	0	300	282	0.725	0.936
seq	921		47	138	0	398	338	0.729	0.949
sha1sum	1046		63	200	0	448	335	0.689	0.940
sha224sum	1182		63	313	0	466	340	0.650	0.947
sha256sum	1190		63	313	0	474	340	0.650	0.947
sha384sum	1466		143	249	0	734	340	0.650	0.902

TABLE XXXV: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
sha512sum	1498		143	249	0	766	340	0.652	0.905
shred	3159		112	178	0	1792	1077	0.780	0.965
shuf	942		47	114	0	393	388	0.755	0.950
sleep	748		47	100	0	313	288	0.732	0.937
sort	11317		243	450	0	2063	8561	0.903	0.979
split	1369		379	181	0	426	383	0.546	0.723
stat	2845		224	257	0	682	1682	0.794	0.921
stdbuf	1931		47	139	0	1387	358	0.742	0.976
stty	1527		53	512	0	600	362	0.616	0.965
sum	2233		63	104	0	1723	343	0.744	0.972
sync	751		47	102	0	314	288	0.731	0.937
tac	12312		444	247	0	9445	2176	0.757	0.964
tail	33975		68	141	0	33205	561	0.751	0.998
tee	8961		47	108	0	8514	292	0.748	0.995
test	959		0	123	0	422	414	0.794	1.000
timeout	1210		362	110	0	334	404	0.564	0.701
touch	6684		308	519	0	4017	1840	0.745	0.954
tr	10057		50	369	0	9295	343	0.736	0.995
true	718		47	92	0	298	281	0.735	0.935
truncate	801		47	106	0	313	335	0.744	0.941
tsort	757		47	104	0	317	289	0.730	0.938
tty	731		47	102	0	301	281	0.728	0.936
uname	1155		55	126	0	301	673	0.805	0.952
unexpand	769		47	104	0	319	299	0.734	0.939
uniq	818		47	128	0	337	306	0.722	0.943
unlink	732		47	98	0	306	281	0.731	0.936
uptime	10247		48	157	0	450	9592	0.973	0.995
users	739		47	98	0	309	285	0.732	0.936
vdir	38591		4921	431	0	19529	13710	0.738	0.872
wc	33696		62	124	0	33091	419	0.750	0.998
who	1345		47	175	0	440	683	0.786	0.965
whoami	734		47	98	0	308	281	0.731	0.936
yes	742		47	98	0	312	285	0.732	0.937

TABLE XXXVI: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	2		0	1	0	1	0	0.500	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	7		0	4	0	3	0	0.464	1.000
chgrp	7		0	4	0	3	0	0.464	1.000
chmod	7		0	4	0	3	0	0.464	1.000
chown	7		0	4	0	3	0	0.464	1.000
chroot	0		0	0	0	0	0	-	-
cksum	3		0	3	0	0	0	0.250	1.000
comm	0		0	0	0	0	0	-	-
cp	7		0	4	0	3	0	0.464	1.000
csplit	0		0	0	0	0	0	-	-

TABLE XXXVI: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
cut	0		0	0	0	0	0	-	-
date	2		0	1	0	1	0	0.500	1.000
dd	7		0	4	0	3	0	0.464	1.000
df	17		0	8	0	4	5	0.588	1.000
dir	10		0	7	0	3	0	0.400	1.000
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	10		0	7	0	3	0	0.400	1.000
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	7		0	4	0	3	0	0.464	1.000
logname	0		0	0	0	0	0	-	-
ls	10		0	7	0	3	0	0.400	1.000
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	1	0	1	0	0.500	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	7		0	4	0	3	0	0.464	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	6	0	1	0	0.321	1.000
od	11		0	4	0	7	0	0.568	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	6	0	1	0	0.321	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	7		0	4	0	3	0	0.464	1.000
realpath	7		0	4	0	3	0	0.464	1.000
rm	7		0	4	0	3	0	0.464	1.000
rmdir	2		0	1	0	1	0	0.500	1.000
runcon	0		0	0	0	0	0	-	-
seq	14		0	13	0	1	0	0.286	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	3	0	0	0	0.250	1.000

TABLE XXXVI: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
shuf	7		0	4	0	3	0	0.464	1.000
sleep	7		0	0	0	2	5	0.929	1.000
sort	22		0	9	0	11	2	0.568	1.000
split	0		0	0	0	0	0	-	-
stat	2		0	1	0	1	0	0.500	1.000
stdbuf	2		0	1	0	1	0	0.500	1.000
stty	2		0	1	0	1	0	0.500	1.000
sum	3		0	3	0	0	0	0.250	1.000
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	15		0	4	0	6	5	0.700	1.000
tee	0		0	0	0	0	0	-	-
test	2		0	1	0	1	0	0.500	1.000
timeout	8		0	0	0	4	4	0.875	1.000
touch	2		0	1	0	1	0	0.500	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	5		0	0	0	4	1	0.800	1.000
users	0		0	0	0	0	0	-	-
vdir	10		0	7	0	3	0	0.400	1.000
wc	4		0	0	0	4	0	0.750	1.000
who	2		0	1	0	1	0	0.500	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XXXVII: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	170		0	20	0	59	91	0.825	1.000
b2sum	140		0	48	0	54	38	0.646	1.000
base32	107		0	32	0	44	31	0.673	1.000
base64	107		0	32	0	44	31	0.673	1.000
basename	104		0	32	0	44	28	0.663	1.000
basenc	138		0	48	0	51	39	0.647	1.000
cat	115		0	40	0	48	27	0.635	1.000
chcon	234		2	52	0	119	61	0.698	0.991
chgrp	230		3	46	0	118	63	0.709	0.987
chmod	217		2	42	0	115	58	0.713	0.991
chown	241		2	48	0	123	68	0.715	0.992
chroot	133		0	32	0	48	53	0.729	1.000
cksum	234		0	99	0	78	57	0.599	1.000
comm	127		0	44	0	54	29	0.634	1.000
cp	403		3	114	0	164	122	0.679	0.993
csplit	1416	10		304	0	1021	81	0.652	0.993
cut	122		0	42	0	49	31	0.641	1.000
date	426		5	202	0	81	138	0.585	0.988

TABLE XXXVII: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
dd	216		0	29	0	73	114	0.815	1.000
df	419		0	83	0	138	198	0.769	1.000
dir	642		1	297	0	199	145	0.574	0.998
dircolors	229		0	119	0	70	40	0.534	1.000
dirname	94		0	28	0	41	25	0.668	1.000
du	1650		13	350	0	1125	162	0.663	0.992
echo	84		0	20	0	40	24	0.702	1.000
env	138		0	46	0	54	38	0.652	1.000
expand	101		0	32	0	45	24	0.651	1.000
expr	1399		10	288	0	1019	82	0.656	0.993
factor	196		1	44	0	84	67	0.719	0.995
false	82		0	20	0	40	22	0.695	1.000
fmt	2126		0	2040	0	52	34	0.274	1.000
fold	99		0	32	0	41	26	0.654	1.000
groups	100		0	26	0	43	31	0.698	1.000
head	125		0	42	0	50	33	0.648	1.000
hostid	93		0	26	0	41	26	0.680	1.000
id	134		0	40	0	47	47	0.688	1.000
join	149		0	45	0	60	44	0.673	1.000
kill	102		0	32	0	41	29	0.664	1.000
link	93		0	26	0	41	26	0.680	1.000
ln	276		0	65	0	120	91	0.715	1.000
logname	94		0	26	0	42	26	0.681	1.000
ls	642		1	297	0	199	145	0.574	0.998
md5sum	132		0	46	0	55	31	0.634	1.000
mkdir	192		0	34	0	65	93	0.783	1.000
mkfifo	100		0	30	0	47	23	0.657	1.000
mknod	105		0	30	0	49	26	0.669	1.000
mktemp	117		0	39	0	48	30	0.647	1.000
mv	379		5	64	0	207	103	0.724	0.987
nice	95		0	28	0	40	27	0.674	1.000
nl	1404		10	320	0	991	83	0.645	0.993
nohup	106		0	26	0	50	30	0.698	1.000
nproc	96		0	30	0	40	26	0.661	1.000
numfmt	184		0	80	0	56	48	0.598	1.000
od	226		0	49	0	62	115	0.769	1.000
paste	103		0	32	0	44	27	0.660	1.000
pathchk	95		0	28	0	43	24	0.666	1.000
pinky	120		0	29	0	58	33	0.698	1.000
pr	218		1	75	0	88	54	0.636	0.995
printenv	93		0	28	0	40	25	0.667	1.000
printf	178		0	21	0	60	97	0.827	1.000
ptx	1540		10	347	0	1043	140	0.655	0.994
pwd	105		0	30	0	50	25	0.667	1.000
readlink	187		0	43	0	78	66	0.723	1.000
realpath	196		0	47	0	83	66	0.714	1.000
rm	236		2	51	0	122	61	0.700	0.992
rmdir	180		0	34	0	55	91	0.782	1.000
runcon	106		0	36	0	47	23	0.634	1.000
seq	193		0	32	0	59	102	0.799	1.000
sha1sum	131		0	46	0	54	31	0.634	1.000
sha224sum	132		0	46	0	55	31	0.634	1.000
sha256sum	132		0	46	0	55	31	0.634	1.000
sha384sum	132		0	46	0	55	31	0.634	1.000
sha512sum	132		0	46	0	55	31	0.634	1.000
shred	174		0	49	0	79	46	0.675	1.000
shuf	218		0	41	0	100	77	0.744	1.000
sleep	99		0	26	0	43	30	0.694	1.000

TABLE XXXVII: Decomposed varnode recovery (compilation = standard)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sort	492		17	113	0	219	143	0.682	0.965
split	162		0	55	0	64	43	0.647	1.000
stat	286		1	44	0	102	139	0.792	0.997
stdbuf	201		0	39	0	61	101	0.779	1.000
stty	331		0	176	0	61	94	0.555	1.000
sum	131		0	35	0	55	41	0.695	1.000
sync	95		0	30	0	43	22	0.650	1.000
tac	1390		10	301	0	1003	76	0.650	0.993
tail	225		0	57	0	89	79	0.711	1.000
tee	108		0	37	0	47	24	0.634	1.000
test	157		0	20	0	49	88	0.826	1.000
timeout	113		0	36	0	43	34	0.666	1.000
touch	391		5	183	0	77	126	0.587	0.987
tr	146		0	54	0	59	33	0.622	1.000
true	82		0	20	0	40	22	0.695	1.000
truncate	100		0	34	0	42	24	0.640	1.000
tsort	118		0	27	0	56	35	0.710	1.000
tty	93		0	30	0	40	23	0.651	1.000
uname	118		0	54	0	42	22	0.568	1.000
unexpand	104		0	34	0	45	25	0.647	1.000
uniq	143		0	55	0	52	36	0.621	1.000
unlink	93		0	26	0	41	26	0.680	1.000
uptime	126		1	26	0	60	39	0.718	0.992
users	102		0	26	0	48	28	0.691	1.000
vdir	642		1	297	0	199	145	0.574	0.998
wc	176		16	40	0	73	47	0.635	0.909
who	222		0	59	0	64	99	0.729	1.000
whoami	94		0	26	0	42	26	0.681	1.000
yes	98		0	26	0	44	28	0.689	1.000

TABLE XXXVIII: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average comparison score [0,1]	Varnode fraction partial recovery
[	1190		0	0	0	0	1190	1.000	1.000
b2sum	1954		0	0	0	0	1954	1.000	1.000
base32	1169		0	0	0	0	1169	1.000	1.000
base64	1197		0	0	0	0	1197	1.000	1.000
basename	844		0	0	0	0	844	1.000	1.000
basenc	1847		0	0	0	0	1847	1.000	1.000
cat	933		0	0	0	0	933	1.000	1.000
chcon	17348		0	0	0	0	17348	1.000	1.000
chgrp	1264		0	0	0	0	1264	1.000	1.000
chmod	1305		0	0	0	0	1305	1.000	1.000
chown	1308		0	0	0	0	1308	1.000	1.000
chroot	933		0	1	0	0	932	0.999	1.000
cksum	31618		0	0	0	0	31618	1.000	1.000
comm	998		0	0	0	0	998	1.000	1.000
cp	4028		0	2	0	2	4024	1.000	1.000
csplit	5511		295	2	0	0	5214	0.946	0.946
cut	5022		0	0	0	0	5022	1.000	1.000
date	8648		9	6	0	0	8633	0.998	0.999
dd	6329		0	0	0	0	6329	1.000	1.000
df	3575		0	7	0	0	3568	0.999	1.000

TABLE XXXVIII: Decomposed varnode recovery (compilation = debug)

	Ground vartnodes	truth	Vartnodes matched @ level NO_MATCH	Vartnodes matched @ level OVERLAP	Vartnodes matched @ level SUBSET	Vartnodes matched @ level ALIGNED	Vartnodes matched @ level MATCH	Vartnode aver- age comparison score [0,1]	Vartnode frac- tion of partial recovery
dir	39259		1255	21	0	0	37983	0.968	0.968
dircolors	5810		3	0	0	0	5807	0.999	0.999
dirname	832		0	0	0	0	832	1.000	1.000
du	8012		295	3	0	0	7714	0.963	0.963
echo	810		0	0	0	0	810	1.000	1.000
env	1464		0	0	0	0	1464	1.000	1.000
expand	898		0	0	0	0	898	1.000	1.000
expr	5706		302	2	0	0	5402	0.947	0.947
factor	4701		53	7	0	0	4641	0.988	0.989
false	801		0	0	0	0	801	1.000	1.000
fmt	15915		4000	0	0	0	11915	0.749	0.749
fold	893		0	0	0	0	893	1.000	1.000
groups	865		0	0	0	0	865	1.000	1.000
head	33790		0	0	0	0	33790	1.000	1.000
hostid	827		0	0	0	0	827	1.000	1.000
id	1007		0	0	0	0	1007	1.000	1.000
join	1004		0	0	0	0	1004	1.000	1.000
kill	1325		0	0	0	0	1325	1.000	1.000
link	826		0	0	0	0	826	1.000	1.000
ln	1991		0	0	0	0	1991	1.000	1.000
logname	827		0	0	0	0	827	1.000	1.000
ls	39259		1255	21	0	0	37983	0.968	0.968
md5sum	1170		0	0	0	0	1170	1.000	1.000
mkdir	3260		0	2	0	0	3258	1.000	1.000
mkfifo	938		0	0	0	0	938	1.000	1.000
mknod	955		0	0	0	0	955	1.000	1.000
mktemp	971		0	0	0	0	971	1.000	1.000
mv	4056		0	1	0	2	4053	1.000	1.000
nice	837		0	0	0	0	837	1.000	1.000
nl	6094		316	2	0	0	5776	0.948	0.948
nohup	874		0	0	0	0	874	1.000	1.000
nproc	865		0	0	0	0	865	1.000	1.000
numfmt	1280		0	0	0	0	1280	1.000	1.000
od	11965		0	1	0	0	11964	1.000	1.000
paste	857		0	0	0	0	857	1.000	1.000
pathchk	869		0	0	0	0	869	1.000	1.000
pinky	3335		224	0	0	0	3111	0.933	0.933
pr	2854		0	0	0	0	2854	1.000	1.000
printenv	826		0	0	0	0	826	1.000	1.000
printf	3369		0	3	0	0	3366	0.999	1.000
ptx	7315		325	9	0	0	6981	0.955	0.956
pwd	969		0	0	0	0	969	1.000	1.000
readlink	1146		0	0	0	0	1146	1.000	1.000
realpath	1051		0	0	0	0	1051	1.000	1.000
rm	1276		0	0	0	0	1276	1.000	1.000
rmdir	3076		0	0	0	0	3076	1.000	1.000
runcon	844		0	0	0	0	844	1.000	1.000
seq	1136		0	0	0	0	1136	1.000	1.000
sha1sum	1178		0	0	0	0	1178	1.000	1.000
sha224sum	1315		0	0	0	0	1315	1.000	1.000
sha256sum	1323		0	0	0	0	1323	1.000	1.000
sha384sum	1599		0	0	0	0	1599	1.000	1.000
sha512sum	1631		0	0	0	0	1631	1.000	1.000
shred	3337		631	0	0	0	2706	0.811	0.811
shuf	1168		0	0	0	0	1168	1.000	1.000
sleep	855		0	0	0	0	855	1.000	1.000
sort	11845		9	1	0	0	11835	0.999	0.999
split	1533		0	2	0	0	1531	0.999	1.000

TABLE XXXVIII: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode aver- age comparison score [0,1]	Varnode fraction partially recovered
stat	3141		0	0	0	0	3141	1.000	1.000
stdbuf	2142		0	0	0	0	2142	1.000	1.000
stty	1868		0	0	0	0	1868	1.000	1.000
sum	2368		0	0	0	0	2368	1.000	1.000
sync	847		0	0	0	0	847	1.000	1.000
tac	13723		302	2	0	0	13419	0.978	0.978
tail	34216		0	6	0	0	34210	1.000	1.000
tee	9070		0	0	0	0	9070	1.000	1.000
test	1126		0	0	0	0	1126	1.000	1.000
timeout	1334		0	0	0	0	1334	1.000	1.000
touch	7107		9	6	0	0	7092	0.998	0.999
tr	10204		0	0	0	0	10204	1.000	1.000
true	801		0	0	0	0	801	1.000	1.000
truncate	902		0	0	0	0	902	1.000	1.000
tsort	876		0	0	0	0	876	1.000	1.000
tty	825		0	0	0	0	825	1.000	1.000
uname	1274		0	0	0	0	1274	1.000	1.000
unexpand	874		0	0	0	0	874	1.000	1.000
uniq	962		0	0	0	0	962	1.000	1.000
unlink	826		0	0	0	0	826	1.000	1.000
uptime	10379		0	0	0	1	10378	1.000	1.000
users	842		0	0	0	0	842	1.000	1.000
vdir	39259		1255	21	0	0	37983	0.968	0.968
wc	33888		9	0	0	0	33879	1.000	1.000
who	1577		0	0	0	0	1577	1.000	1.000
whoami	829		0	0	0	0	829	1.000	1.000
yes	841		0	0	0	0	841	1.000	1.000

TABLE XXXIX: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	1010		0	0	0	0	1010	1.000	1.000
b2sum	1813		0	0	0	0	1813	1.000	1.000
base32	1061		0	0	0	0	1061	1.000	1.000
base64	1089		0	0	0	0	1089	1.000	1.000
basename	739		0	0	0	0	739	1.000	1.000
basenc	1707		0	0	0	0	1707	1.000	1.000
cat	817		0	0	0	0	817	1.000	1.000
chcon	17106		0	0	0	0	17106	1.000	1.000
chgrp	1026		0	0	0	0	1026	1.000	1.000
chmod	1080		0	0	0	0	1080	1.000	1.000
chown	1059		0	0	0	0	1059	1.000	1.000
chroot	799		0	1	0	0	798	0.999	1.000
cksum	31380		0	0	0	0	31380	1.000	1.000
comm	870		0	0	0	0	870	1.000	1.000
cp	3616		0	2	0	2	3612	0.999	1.000
csplit	4073		295	2	0	0	3776	0.927	0.928
cut	4899		0	0	0	0	4899	1.000	1.000
date	8190		8	6	0	0	8176	0.998	0.999
dd	6097		0	0	0	0	6097	1.000	1.000
df	3126		0	7	0	0	3119	0.998	1.000
dir	38591		1255	21	0	0	37315	0.967	0.967
dircolors	5577		3	0	0	0	5574	0.999	0.999



TABLE XXXIX: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
dirname	737		0	0	0	0	737	1.000	1.000
du	6328		295	3	0	0	6030	0.953	0.953
echo	725		0	0	0	0	725	1.000	1.000
env	1323		0	0	0	0	1323	1.000	1.000
expand	796		0	0	0	0	796	1.000	1.000
expr	4280		302	2	0	0	3976	0.929	0.929
factor	4491		41	5	0	0	4445	0.990	0.991
false	718		0	0	0	0	718	1.000	1.000
fmt	13788		4000	0	0	0	9788	0.710	0.710
fold	793		0	0	0	0	793	1.000	1.000
groups	764		0	0	0	0	764	1.000	1.000
head	33664		0	0	0	0	33664	1.000	1.000
hostid	733		0	0	0	0	733	1.000	1.000
id	872		0	0	0	0	872	1.000	1.000
join	854		0	0	0	0	854	1.000	1.000
kill	1222		0	0	0	0	1222	1.000	1.000
link	732		0	0	0	0	732	1.000	1.000
ln	1704		0	0	0	0	1704	1.000	1.000
logname	732		0	0	0	0	732	1.000	1.000
ls	38591		1255	21	0	0	37315	0.967	0.967
md5sum	1037		0	0	0	0	1037	1.000	1.000
mkdir	3057		0	2	0	0	3055	1.000	1.000
mkfifo	837		0	0	0	0	837	1.000	1.000
mknod	849		0	0	0	0	849	1.000	1.000
mktemp	853		0	0	0	0	853	1.000	1.000
mv	3668		0	1	0	2	3665	1.000	1.000
nice	741		0	0	0	0	741	1.000	1.000
nl	4669		316	2	0	0	4351	0.932	0.932
nohup	767		0	0	0	0	767	1.000	1.000
nproc	768		0	0	0	0	768	1.000	1.000
numfmt	1088		0	0	0	0	1088	1.000	1.000
od	11712		0	1	0	0	11711	1.000	1.000
paste	753		0	0	0	0	753	1.000	1.000
pathchk	771		0	0	0	0	771	1.000	1.000
pinky	3214		224	0	0	0	2990	0.930	0.930
pr	2634		0	0	0	0	2634	1.000	1.000
printenv	732		0	0	0	0	732	1.000	1.000
printf	3173		0	3	0	0	3170	0.999	1.000
ptx	5741		325	7	0	0	5409	0.942	0.943
pwd	863		0	0	0	0	863	1.000	1.000
readlink	948		0	0	0	0	948	1.000	1.000
realpath	844		0	0	0	0	844	1.000	1.000
rm	1032		0	0	0	0	1032	1.000	1.000
rmdir	2886		0	0	0	0	2886	1.000	1.000
runcon	737		0	0	0	0	737	1.000	1.000
seq	921		0	0	0	0	921	1.000	1.000
sha1sum	1046		0	0	0	0	1046	1.000	1.000
sha224sum	1182		0	0	0	0	1182	1.000	1.000
sha256sum	1190		0	0	0	0	1190	1.000	1.000
sha384sum	1466		0	0	0	0	1466	1.000	1.000
sha512sum	1498		0	0	0	0	1498	1.000	1.000
shred	3159		631	0	0	0	2528	0.800	0.800
shuf	942		0	0	0	0	942	1.000	1.000
sleep	748		0	0	0	0	748	1.000	1.000
sort	11317		9	1	0	0	11307	0.999	0.999
split	1369		0	2	0	0	1367	0.999	1.000
stat	2845		0	0	0	0	2845	1.000	1.000
stdbuf	1931		0	0	0	0	1931	1.000	1.000

TABLE XXXIX: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
stty	1527		0	0	0	0	1527	1.000	1.000
sum	2233		0	0	0	0	2233	1.000	1.000
sync	751		0	0	0	0	751	1.000	1.000
tac	12312		302	2	0	0	12008	0.975	0.975
tail	33975		0	6	0	0	33969	1.000	1.000
tee	8961		0	0	0	0	8961	1.000	1.000
test	959		0	0	0	0	959	1.000	1.000
timeout	1210		0	0	0	0	1210	1.000	1.000
touch	6684		8	6	0	0	6670	0.998	0.999
tr	10057		0	0	0	0	10057	1.000	1.000
true	718		0	0	0	0	718	1.000	1.000
truncate	801		0	0	0	0	801	1.000	1.000
tsort	757		0	0	0	0	757	1.000	1.000
tty	731		0	0	0	0	731	1.000	1.000
uname	1155		0	0	0	0	1155	1.000	1.000
unexpand	769		0	0	0	0	769	1.000	1.000
uniq	818		0	0	0	0	818	1.000	1.000
unlink	732		0	0	0	0	732	1.000	1.000
uptime	10247		0	0	0	0	10247	1.000	1.000
users	739		0	0	0	0	739	1.000	1.000
vdir	38591		1255	21	0	0	37315	0.967	0.967
wc	33696		9	0	0	0	33687	1.000	1.000
who	1345		0	0	0	0	1345	1.000	1.000
whoami	734		0	0	0	0	734	1.000	1.000
yes	742		0	0	0	0	742	1.000	1.000

TABLE XL: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partially recovered
[	2		0	0	0	0	2	1.000	1.000
b2sum	0		0	0	0	0	0	-	-
base32	0		0	0	0	0	0	-	-
base64	0		0	0	0	0	0	-	-
basename	0		0	0	0	0	0	-	-
basenc	0		0	0	0	0	0	-	-
cat	0		0	0	0	0	0	-	-
chcon	7		0	0	0	0	7	1.000	1.000
chgrp	7		0	0	0	0	7	1.000	1.000
chmod	7		0	0	0	0	7	1.000	1.000
chown	7		0	0	0	0	7	1.000	1.000
chroot	0		0	0	0	0	0	-	-
cksum	3		0	0	0	0	3	1.000	1.000
comm	0		0	0	0	0	0	-	-
cp	7		0	0	0	0	7	1.000	1.000
csplit	0		0	0	0	0	0	-	-
cut	0		0	0	0	0	0	-	-
date	2		0	0	0	0	2	1.000	1.000
dd	7		0	0	0	0	7	1.000	1.000
df	17		0	0	0	0	17	1.000	1.000
dir	10		0	0	0	0	10	1.000	1.000
dircolors	0		0	0	0	0	0	-	-
dirname	0		0	0	0	0	0	-	-
du	10		0	0	0	0	10	1.000	1.000

TABLE XL: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
echo	0		0	0	0	0	0	-	-
env	0		0	0	0	0	0	-	-
expand	0		0	0	0	0	0	-	-
expr	0		0	0	0	0	0	-	-
factor	0		0	0	0	0	0	-	-
false	0		0	0	0	0	0	-	-
fmt	0		0	0	0	0	0	-	-
fold	0		0	0	0	0	0	-	-
groups	0		0	0	0	0	0	-	-
head	0		0	0	0	0	0	-	-
hostid	0		0	0	0	0	0	-	-
id	0		0	0	0	0	0	-	-
join	0		0	0	0	0	0	-	-
kill	0		0	0	0	0	0	-	-
link	0		0	0	0	0	0	-	-
ln	7		0	0	0	0	7	1.000	1.000
logname	0		0	0	0	0	0	-	-
ls	10		0	0	0	0	10	1.000	1.000
md5sum	0		0	0	0	0	0	-	-
mkdir	2		0	0	0	0	2	1.000	1.000
mkfifo	0		0	0	0	0	0	-	-
mknod	0		0	0	0	0	0	-	-
mktemp	0		0	0	0	0	0	-	-
mv	7		0	0	0	0	7	1.000	1.000
nice	0		0	0	0	0	0	-	-
nl	0		0	0	0	0	0	-	-
nohup	0		0	0	0	0	0	-	-
nproc	0		0	0	0	0	0	-	-
numfmt	7		0	0	0	0	7	1.000	1.000
od	11		0	0	0	0	11	1.000	1.000
paste	0		0	0	0	0	0	-	-
pathchk	0		0	0	0	0	0	-	-
pinky	0		0	0	0	0	0	-	-
pr	0		0	0	0	0	0	-	-
printenv	0		0	0	0	0	0	-	-
printf	7		0	0	0	0	7	1.000	1.000
ptx	0		0	0	0	0	0	-	-
pwd	0		0	0	0	0	0	-	-
readlink	7		0	0	0	0	7	1.000	1.000
realpath	7		0	0	0	0	7	1.000	1.000
rm	7		0	0	0	0	7	1.000	1.000
rmdir	2		0	0	0	0	2	1.000	1.000
runcon	0		0	0	0	0	0	-	-
seq	14		0	0	0	0	14	1.000	1.000
sha1sum	0		0	0	0	0	0	-	-
sha224sum	0		0	0	0	0	0	-	-
sha256sum	0		0	0	0	0	0	-	-
sha384sum	0		0	0	0	0	0	-	-
sha512sum	0		0	0	0	0	0	-	-
shred	3		0	0	0	0	3	1.000	1.000
shuf	7		0	0	0	0	7	1.000	1.000
sleep	7		0	0	0	0	7	1.000	1.000
sort	22		0	0	0	0	22	1.000	1.000
split	0		0	0	0	0	0	-	-
stat	2		0	0	0	0	2	1.000	1.000
stdbuf	2		0	0	0	0	2	1.000	1.000
stty	2		0	0	0	0	2	1.000	1.000
sum	3		0	0	0	0	3	1.000	1.000

TABLE XL: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
sync	0		0	0	0	0	0	-	-
tac	0		0	0	0	0	0	-	-
tail	15		0	0	0	0	15	1.000	1.000
tee	0		0	0	0	0	0	-	-
test	2		0	0	0	0	2	1.000	1.000
timeout	8		0	0	0	0	8	1.000	1.000
touch	2		0	0	0	0	2	1.000	1.000
tr	0		0	0	0	0	0	-	-
true	0		0	0	0	0	0	-	-
truncate	0		0	0	0	0	0	-	-
tsort	0		0	0	0	0	0	-	-
tty	0		0	0	0	0	0	-	-
uname	0		0	0	0	0	0	-	-
unexpand	0		0	0	0	0	0	-	-
uniq	0		0	0	0	0	0	-	-
unlink	0		0	0	0	0	0	-	-
uptime	5		0	0	0	0	5	1.000	1.000
users	0		0	0	0	0	0	-	-
vdir	10		0	0	0	0	10	1.000	1.000
wc	4		0	0	0	0	4	1.000	1.000
who	2		0	0	0	0	2	1.000	1.000
whoami	0		0	0	0	0	0	-	-
yes	0		0	0	0	0	0	-	-

TABLE XLI: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
[	170		0	0	0	0	170	1.000	1.000
b2sum	140		0	0	0	0	140	1.000	1.000
base32	107		0	0	0	0	107	1.000	1.000
base64	107		0	0	0	0	107	1.000	1.000
basename	104		0	0	0	0	104	1.000	1.000
basenc	138		0	0	0	0	138	1.000	1.000
cat	115		0	0	0	0	115	1.000	1.000
chcon	234		0	0	0	0	234	1.000	1.000
chgrp	230		0	0	0	0	230	1.000	1.000
chmod	217		0	0	0	0	217	1.000	1.000
chown	241		0	0	0	0	241	1.000	1.000
chroot	133		0	0	0	0	133	1.000	1.000
cksum	234		0	0	0	0	234	1.000	1.000
comm	127		0	0	0	0	127	1.000	1.000
cp	403		0	0	0	0	403	1.000	1.000
csplit	1416		0	0	0	0	1416	1.000	1.000
cut	122		0	0	0	0	122	1.000	1.000
date	426	1	0	0	0	0	425	0.998	0.998
dd	216		0	0	0	0	216	1.000	1.000
df	419		0	0	0	0	419	1.000	1.000
dir	642		0	0	0	0	642	1.000	1.000
dircolors	229		0	0	0	0	229	1.000	1.000
dirname	94		0	0	0	0	94	1.000	1.000
du	1650		0	0	0	0	1650	1.000	1.000
echo	84		0	0	0	0	84	1.000	1.000
env	138		0	0	0	0	138	1.000	1.000

TABLE XLI: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
expand	101		0	0	0	0	101	1.000	1.000
expr	1399		0	0	0	0	1399	1.000	1.000
factor	196		12	1	0	0	183	0.935	0.939
false	82		0	0	0	0	82	1.000	1.000
fmt	2126		0	0	0	0	2126	1.000	1.000
fold	99		0	0	0	0	99	1.000	1.000
groups	100		0	0	0	0	100	1.000	1.000
head	125		0	0	0	0	125	1.000	1.000
hostid	93		0	0	0	0	93	1.000	1.000
id	134		0	0	0	0	134	1.000	1.000
join	149		0	0	0	0	149	1.000	1.000
kill	102		0	0	0	0	102	1.000	1.000
link	93		0	0	0	0	93	1.000	1.000
ln	276		0	0	0	0	276	1.000	1.000
logname	94		0	0	0	0	94	1.000	1.000
ls	642		0	0	0	0	642	1.000	1.000
md5sum	132		0	0	0	0	132	1.000	1.000
mkdir	192		0	0	0	0	192	1.000	1.000
mkfifo	100		0	0	0	0	100	1.000	1.000
mknod	105		0	0	0	0	105	1.000	1.000
mktemp	117		0	0	0	0	117	1.000	1.000
mv	379		0	0	0	0	379	1.000	1.000
nice	95		0	0	0	0	95	1.000	1.000
nl	1404		0	0	0	0	1404	1.000	1.000
nohup	106		0	0	0	0	106	1.000	1.000
nproc	96		0	0	0	0	96	1.000	1.000
numfmt	184		0	0	0	0	184	1.000	1.000
od	226		0	0	0	0	226	1.000	1.000
paste	103		0	0	0	0	103	1.000	1.000
pathchk	95		0	0	0	0	95	1.000	1.000
pinky	120		0	0	0	0	120	1.000	1.000
pr	218		0	0	0	0	218	1.000	1.000
printenv	93		0	0	0	0	93	1.000	1.000
printf	178		0	0	0	0	178	1.000	1.000
ptx	1540		0	1	0	0	1539	1.000	1.000
pwd	105		0	0	0	0	105	1.000	1.000
readlink	187		0	0	0	0	187	1.000	1.000
realpath	196		0	0	0	0	196	1.000	1.000
rm	236		0	0	0	0	236	1.000	1.000
rmdir	180		0	0	0	0	180	1.000	1.000
runcon	106		0	0	0	0	106	1.000	1.000
seq	193		0	0	0	0	193	1.000	1.000
sha1sum	131		0	0	0	0	131	1.000	1.000
sha224sum	132		0	0	0	0	132	1.000	1.000
sha256sum	132		0	0	0	0	132	1.000	1.000
sha384sum	132		0	0	0	0	132	1.000	1.000
sha512sum	132		0	0	0	0	132	1.000	1.000
shred	174		0	0	0	0	174	1.000	1.000
shuf	218		0	0	0	0	218	1.000	1.000
sleep	99		0	0	0	0	99	1.000	1.000
sort	492		0	0	0	0	492	1.000	1.000
split	162		0	0	0	0	162	1.000	1.000
stat	286		0	0	0	0	286	1.000	1.000
stdbuf	201		0	0	0	0	201	1.000	1.000
stty	331		0	0	0	0	331	1.000	1.000
sum	131		0	0	0	0	131	1.000	1.000
sync	95		0	0	0	0	95	1.000	1.000
tac	1390		0	0	0	0	1390	1.000	1.000

TABLE XLI: Decomposed varnode recovery (compilation = debug)

	Ground varnodes	truth	Varnodes matched @ level NO_MATCH	Varnodes matched @ level OVERLAP	Varnodes matched @ level SUBSET	Varnodes matched @ level ALIGNED	Varnodes matched @ level MATCH	Varnode average compare score [0,1]	Varnode fraction partial recovery
tail	225		0	0	0	0	225	1.000	1.000
tee	108		0	0	0	0	108	1.000	1.000
test	157		0	0	0	0	157	1.000	1.000
timeout	113		0	0	0	0	113	1.000	1.000
touch	391		1	0	0	0	390	0.997	0.997
tr	146		0	0	0	0	146	1.000	1.000
true	82		0	0	0	0	82	1.000	1.000
truncate	100		0	0	0	0	100	1.000	1.000
tsort	118		0	0	0	0	118	1.000	1.000
tty	93		0	0	0	0	93	1.000	1.000
uname	118		0	0	0	0	118	1.000	1.000
unexpand	104		0	0	0	0	104	1.000	1.000
uniq	143		0	0	0	0	143	1.000	1.000
unlink	93		0	0	0	0	93	1.000	1.000
uptime	126		0	0	0	1	125	0.998	1.000
users	102		0	0	0	0	102	1.000	1.000
vdir	642		0	0	0	0	642	1.000	1.000
wc	176		0	0	0	0	176	1.000	1.000
who	222		0	0	0	0	222	1.000	1.000
whoami	94		0	0	0	0	94	1.000	1.000
yes	98		0	0	0	0	98	1.000	1.000

TABLE XLII: Data bytes recovery (compilation = stripped)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
[	4463	3500	963	0.784
b2sum	4472	3152	1320	0.705
base32	2671	1668	1003	0.624
base64	2699	1664	1035	0.617
basename	2193	1478	715	0.674
basenc	3793	1919	1874	0.506
cat	2644	1771	873	0.670
chcon	20631	19308	1323	0.936
chgrp	4803	3263	1540	0.679
chmod	4776	3154	1622	0.660
chown	4964	3400	1564	0.685
chroot	2626	1911	715	0.728
cksum	161248	10363	150885	0.064
comm	2785	2002	783	0.719
cp	12062	7133	4929	0.591
csplit	31324	29232	2092	0.933
cut	6800	5916	884	0.870
date	18373	13069	5304	0.711
dd	11354	8493	2861	0.748
df	13944	10093	3851	0.724
dir	52738	37069	15669	0.703
dircolors	8180	1922	6258	0.235
dirname	2101	1449	652	0.690
du	37523	34187	3336	0.911
echo	1915	1392	523	0.727
env	4112	2469	1643	0.600
expand	2319	1593	726	0.687
expr	30656	28585	2071	0.932
factor	23027	9450	13577	0.410
false	1885	1362	523	0.723
fmt	47599	1764	45835	0.037

Continued on

TABLE XLII: Data bytes recovery (compilation = stripped)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
fold	2276	1525	751	0.670
groups	2165	1525	640	0.704
head	35911	34944	967	0.973
hostid	2057	1430	627	0.695
id	2721	1815	906	0.667
join	3126	2223	903	0.711
kill	2834	1586	1248	0.560
link	2053	1426	627	0.695
ln	9661	5479	4182	0.567
logname	2061	1434	627	0.696
ls	52738	37069	15669	0.703
md5sum	3345	2318	1027	0.693
mkdir	6846	5566	1280	0.813
mkfifo	2546	1610	936	0.632
mknod	2655	1719	936	0.647
mktemp	2681	1823	858	0.680
mv	12285	7791	4494	0.634
nice	2122	1471	651	0.693
nl	31091	27958	3133	0.899
nohup	2299	1668	631	0.726
nproc	2358	1675	683	0.710
numfmt	4029	2668	1361	0.662
od	16365	14702	1663	0.898
paste	2217	1502	715	0.677
pathchk	2344	1685	659	0.719
pinky	5002	4172	830	0.834
pr	6996	5411	1585	0.773
printenv	2052	1401	651	0.683
printf	6293	5526	767	0.878
ptx	38535	34166	4369	0.887
pwd	3093	1738	1355	0.562
readlink	6662	3695	2967	0.555
realpath	6753	3602	3151	0.533
rm	5075	3610	1465	0.711
rmdir	5987	5080	907	0.849
runcon	2214	1435	779	0.648
seq	4357	3526	831	0.809
sha1sum	3349	2322	1027	0.693
sha224sum	3869	2586	1283	0.668
sha256sum	3877	2594	1283	0.669
sha384sum	6229	4494	1735	0.721
sha512sum	6261	4526	1735	0.723
shred	6721	5128	1593	0.763
shuf	4465	3382	1083	0.757
sleep	2255	1620	635	0.718
sort	20811	16580	4231	0.797
split	4729	2821	1908	0.597
stat	9167	7372	1795	0.804
stdbuf	5343	4516	827	0.845
stty	8535	3418	5117	0.400
sum	4413	3681	732	0.834
sync	2146	1459	687	0.680
tac	38578	28162	10416	0.730
tail	38862	36536	2326	0.940
tee	10555	9788	767	0.927
test	4288	3376	912	0.787
timeout	3663	2456	1207	0.670
touch	15837	10984	4853	0.694
tr	12260	2461	9799	0.201
true	1885	1362	523	0.723
truncate	2585	1654	931	0.640

Continued on

TABLE XLII: Data bytes recovery (compilation = stripped)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
tsort	2391	1756	635	0.734
tty	2062	1379	683	0.669
uname	2860	1793	1067	0.627
unexpand	2344	1621	723	0.692
uniq	2943	1912	1031	0.650
unlink	2053	1426	627	0.695
uptime	13110	12351	759	0.942
users	2167	1540	627	0.711
vdir	52738	37069	15669	0.703
wc	36613	2619	33994	0.072
who	5007	3714	1293	0.742
whoami	2069	1442	627	0.697
yes	2166	1539	627	0.711

TABLE XLIII: Data bytes recovery (compilation = standard)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
[	4463	4320	143	0.968
b2sum	4472	4304	168	0.962
base32	2671	2548	123	0.954
base64	2699	2608	91	0.966
basename	2193	2102	91	0.959
basenc	3793	3423	370	0.902
cat	2644	2553	91	0.966
chcon	20631	20496	135	0.993
chgrp	4803	4651	152	0.968
chmod	4776	4602	174	0.964
chown	4964	4820	144	0.971
chroot	2626	2535	91	0.965
cksum	161248	29876	131372	0.185
comm	2785	2690	95	0.966
cp	12062	11214	848	0.930
csplit	31324	30228	1096	0.965
cut	6800	6709	91	0.987
date	18373	17641	732	0.960
dd	11354	10131	1223	0.892
df	13944	11740	2204	0.842
dir	52738	44599	8139	0.846
dircolors	8180	3281	4899	0.401
dirname	2101	2010	91	0.957
du	37523	36212	1311	0.965
echo	1915	1824	91	0.952
env	4112	3590	522	0.873
expand	2319	2227	92	0.960
expr	30656	29313	1343	0.956
factor	23027	22319	708	0.969
false	1885	1794	91	0.952
fmt	47599	47508	91	0.998
fold	2276	2184	92	0.960
groups	2165	2074	91	0.958
head	35911	35820	91	0.997
hostid	2057	1958	99	0.952
id	2721	2630	91	0.967
join	3126	3023	103	0.967
kill	2834	2210	624	0.780
link	2053	1954	99	0.952
ln	9661	7423	2238	0.768
logname	2061	1962	99	0.952
ls	52738	44599	8139	0.846

Continued on



TABLE XLIII: Data bytes recovery (compilation = standard)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
md5sum	3345	3230	115	0.966
mkdir	6846	6714	132	0.981
mkfifo	2546	2438	108	0.958
mknod	2655	2547	108	0.959
mktemp	2681	2527	154	0.943
mv	12285	11168	1117	0.909
nice	2122	2031	91	0.957
nl	31091	29976	1115	0.964
nohup	2299	2196	103	0.955
nproc	2358	2267	91	0.961
numfmt	4029	3924	105	0.974
od	16365	16171	194	0.988
paste	2217	2126	91	0.959
pathchk	2344	2253	91	0.961
pinky	5002	4911	91	0.982
pr	6996	6799	197	0.972
printenv	2052	1961	91	0.956
printf	6293	5994	299	0.952
ptx	38535	37006	1529	0.960
pwd	3093	3002	91	0.971
readlink	6662	4499	2163	0.675
realpath	6753	4590	2163	0.680
rm	5075	4806	269	0.947
rmdir	5987	5884	103	0.983
runcon	2214	2123	91	0.959
seq	4357	4208	149	0.966
sha1sum	3349	3234	115	0.966
sha224sum	3869	3754	115	0.970
sha256sum	3877	3762	115	0.970
sha384sum	6229	5470	759	0.878
sha512sum	6261	5502	759	0.879
shred	6721	6533	188	0.972
shuf	4465	4362	103	0.977
sleep	2255	2148	107	0.953
sort	20811	19990	821	0.961
split	4729	4074	655	0.861
stat	9167	8617	550	0.940
stdbuf	5343	5240	103	0.981
stty	8535	8403	132	0.985
sum	4413	4290	123	0.972
sync	2146	2051	95	0.956
tac	38578	37482	1096	0.972
tail	38862	38568	294	0.992
tee	10555	10460	95	0.991
test	4288	4196	92	0.979
timeout	3663	3144	519	0.858
touch	15837	15142	695	0.956
tr	12260	12165	95	0.992
true	1885	1794	91	0.952
truncate	2585	2494	91	0.965
tsort	2391	2284	107	0.955
tty	2062	1971	91	0.956
uname	2860	2761	99	0.965
unexpand	2344	2253	91	0.961
uniq	2943	2844	99	0.966
unlink	2053	1954	99	0.952
uptime	13110	12971	139	0.989
users	2167	2068	99	0.954
vdir	52738	44599	8139	0.846
wc	36613	3528	33085	0.096
who	5007	4904	103	0.979

Continued on

TABLE XLIII: Data bytes recovery (compilation = standard)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
whoami	2069	1970	99	0.952
yes	2166	2067	99	0.954

TABLE XLIV: Data bytes recovery (compilation = debug)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
[	4463	4463	0	1.000
b2sum	4472	4472	0	1.000
base32	2671	2671	0	1.000
base64	2699	2699	0	1.000
basename	2193	2193	0	1.000
basenc	3793	3793	0	1.000
cat	2644	2644	0	1.000
chcon	20631	20631	0	1.000
chgrp	4803	4803	0	1.000
chmod	4776	4776	0	1.000
chown	4964	4964	0	1.000
chroot	2626	2626	0	1.000
cksum	161248	161248	0	1.000
comm	2785	2785	0	1.000
cp	12062	12062	0	1.000
csplit	31324	31084	240	0.992
cut	6800	6800	0	1.000
date	18373	18321	52	0.997
dd	11354	11354	0	1.000
df	13944	13944	0	1.000
dir	52738	51468	1270	0.976
dircolors	8180	8180	0	1.000
dirname	2101	2101	0	1.000
du	37523	37283	240	0.994
echo	1915	1915	0	1.000
env	4112	4112	0	1.000
expand	2319	2319	0	1.000
expr	30656	30416	240	0.992
factor	23027	22782	245	0.989
false	1885	1885	0	1.000
fmt	47599	47599	0	1.000
fold	2276	2276	0	1.000
groups	2165	2165	0	1.000
head	35911	35911	0	1.000
hostid	2057	2057	0	1.000
id	2721	2721	0	1.000
join	3126	3126	0	1.000
kill	2834	2834	0	1.000
link	2053	2053	0	1.000
ln	9661	9661	0	1.000
logname	2061	2061	0	1.000
ls	52738	51468	1270	0.976
md5sum	3345	3345	0	1.000
mkdir	6846	6846	0	1.000
mkfifo	2546	2546	0	1.000
mknod	2655	2655	0	1.000
mktemp	2681	2681	0	1.000
mv	12285	12285	0	1.000
nice	2122	2122	0	1.000
nl	31091	30851	240	0.992
nohup	2299	2299	0	1.000
nproc	2358	2358	0	1.000
numfmt	4029	4029	0	1.000

Continued on

TABLE XLIV: Data bytes recovery (compilation = debug)

	Ground truth data bytes	Bytes found	Bytes missed	Bytes recovery fraction
od	16365	16365	0	1.000
paste	2217	2217	0	1.000
pathchk	2344	2344	0	1.000
pinky	5002	4778	224	0.955
pr	6996	6996	0	1.000
printenv	2052	2052	0	1.000
printf	6293	6293	0	1.000
ptx	38535	38279	256	0.993
pwd	3093	3093	0	1.000
readlink	6662	6662	0	1.000
realpath	6753	6753	0	1.000
rm	5075	5075	0	1.000
rmdir	5987	5987	0	1.000
runcon	2214	2214	0	1.000
seq	4357	4357	0	1.000
sha1sum	3349	3349	0	1.000
sha224sum	3869	3869	0	1.000
sha256sum	3877	3877	0	1.000
sha384sum	6229	6229	0	1.000
sha512sum	6261	6261	0	1.000
shred	6721	6090	631	0.906
shuf	4465	4465	0	1.000
sleep	2255	2255	0	1.000
sort	20811	20811	0	1.000
split	4729	4729	0	1.000
stat	9167	9167	0	1.000
stdbuf	5343	5343	0	1.000
stty	8535	8535	0	1.000
sum	4413	4413	0	1.000
sync	2146	2146	0	1.000
tac	38578	38338	240	0.994
tail	38862	38862	0	1.000
tee	10555	10555	0	1.000
test	4288	4288	0	1.000
timeout	3663	3663	0	1.000
touch	15837	15785	52	0.997
tr	12260	12260	0	1.000
true	1885	1885	0	1.000
truncate	2585	2585	0	1.000
tsort	2391	2391	0	1.000
tty	2062	2062	0	1.000
uname	2860	2860	0	1.000
unexpand	2344	2344	0	1.000
uniq	2943	2943	0	1.000
unlink	2053	2053	0	1.000
uptime	13110	13110	0	1.000
users	2167	2167	0	1.000
vdir	52738	51468	1270	0.976
wc	36613	36613	0	1.000
who	5007	5007	0	1.000
whoami	2069	2069	0	1.000
yes	2166	2166	0	1.000

TABLE XLV: Array recovery (compilation = stripped)

	Ground truth varnodes	Array comparisons array	Array varnodes inferred array	as array	Array varnodes inferred as array	Array length (elements) average error	Array length (elements) average error	Array size (bytes) average error	Array size (bytes) average error	size error	size error
[	15	6	6		0.400	3.667	0.132	4.833	0.132		
b2sum	24	23	13		0.542	30.522	26.451	37.348	0.522		
base32	12	3	3		0.250	2.667	0.042	5.000	0.042		
base64	12	3	3		0.250	2.667	0.042	5.000	0.042		
basename	10	3	3		0.300	2.667	0.042	5.000	0.042		
basenc	20	4	4		0.200	2.000	0.032	3.750	0.032		
cat	11	3	3		0.273	2.667	0.042	5.000	0.042		
chcon	18	8	8		0.444	6.000	0.048	6.875	0.048		
chgrp	15	5	5		0.333	2.800	0.083	4.200	0.083		
chmod	19	6	6		0.316	4.667	0.194	5.833	0.194		
chown	16	6	6		0.375	2.833	0.093	4.000	0.093		
chroot	11	4	4		0.364	2.750	0.068	4.500	0.068		
cksum	66	39	27		0.409	755.590	16.511	6749.256	0.501		
comm	22	12	12		0.545	18.250	2.054	4.000	0.138		
cp	40	10	9		0.225	8.200	1.485	9.300	0.185		
csplit	35	23	21		0.600	123.261	0.537	359.087	0.150		
cut	12	4	4		0.333	4.000	0.032	5.750	0.032		
date	63	28	26		0.413	85.071	0.571	81.036	0.357		
dd	34	11	9		0.265	360.455	0.230	361.091	0.230		
df	25	8	8		0.320	86.125	3.893	87.000	3.893		
dir	71	32	31		0.437	156.688	5.807	156.906	5.807		
dircolors	13	3	3		0.231	2.667	0.042	5.000	0.042		
dirname	10	3	3		0.300	2.667	0.042	5.000	0.042		
du	51	26	23		0.451	148.962	0.536	357.577	0.194		
echo	9	3	3		0.333	2.667	0.042	5.000	0.042		
env	18	8	8		0.444	4.125	0.180	5.000	0.180		
expand	13	3	3		0.231	2.667	0.042	5.000	0.042		
expr	33	20	18		0.545	141.550	0.590	412.750	0.145		
factor	37	18	18		0.486	15.667	13.571	3.667	0.168		
false	9	3	3		0.333	2.667	0.042	5.000	0.042		
fmt	12	3	3		0.250	2.667	0.042	5.000	0.042		
fold	12	3	3		0.250	2.667	0.042	5.000	0.042		
groups	11	3	3		0.273	2.667	0.042	5.000	0.042		
head	18	10	10		0.556	4.900	0.192	7.700	0.192		
hostid	12	3	3		0.250	2.667	0.042	5.000	0.042		
id	14	4	4		0.286	2.750	0.068	4.500	0.068		
join	18	5	5		0.278	2.800	0.625	3.000	0.025		
kill	14	5	5		0.357	3.600	0.131	5.000	0.131		
link	12	3	3		0.250	2.667	0.042	5.000	0.042		
ln	22	5	5		0.227	4.800	0.038	6.200	0.038		
logname	12	3	3		0.250	2.667	0.042	5.000	0.042		
ls	71	32	31		0.437	156.688	5.807	156.906	5.807		
md5sum	16	5	5		0.312	3.200	0.105	4.600	0.105		
mkdir	19	7	7		0.368	4.857	0.381	7.571	0.381		
mkfifo	12	4	4		0.333	5.500	0.166	7.250	0.166		
mknod	12	4	4		0.333	5.500	0.166	7.250	0.166		
mktemp	12	3	3		0.250	2.667	0.042	5.000	0.042		
mv	34	10	9		0.265	8.200	1.485	9.300	0.185		
nice	10	3	3		0.300	2.667	0.042	5.000	0.042		
nl	36	19	17		0.472	148.579	0.620	434.053	0.151		
nohup	13	3	3		0.231	2.667	0.042	5.000	0.042		
nproc	10	3	3		0.300	2.667	0.042	5.000	0.042		
numfmt	20	5	5		0.250	12.600	0.185	5.400	0.050		
od	40	12	12		0.300	3.917	0.146	5.667	0.146		
paste	10	3	3		0.300	2.667	0.042	5.000	0.042		
pathchk	10	3	3		0.300	2.667	0.042	5.000	0.042		
pinky	17	8	8		0.471	33.500	0.916	34.375	0.916		
pr	20	10	9		0.450	103.500	0.192	104.200	0.192		

TABLE XLV: Array recovery (compilation = stripped)

	Ground truth varnodes	array comparisons	Array varnodes inferred array	as	Array varnodes inferred array	as	Array length (elements) average error	Array length (elements) average error	Array size (bytes) average error	Array size (bytes) average error	size error ratio
printenv	10	3	3		0.300		2.667	0.042	5.000	0.042	
printf	17	8	8		0.471		27.750	0.185	28.625	0.185	
ptx	39	20	18		0.462		141.300	0.596	412.500	0.151	
pwd	10	3	3		0.300		2.667	0.042	5.000	0.042	
readlink	12	4	4		0.333		4.000	0.047	5.750	0.047	
realpath	11	3	3		0.273		2.667	0.042	5.000	0.042	
rm	15	3	3		0.200		2.667	0.042	5.000	0.042	
rmdir	14	5	5		0.357		3.200	0.026	4.600	0.026	
runcon	10	3	3		0.300		2.667	0.042	5.000	0.042	
seq	15	4	4		0.267		2.000	0.032	3.750	0.032	
sha1sum	16	6	6		0.375		3.333	0.146	10.500	0.146	
sha224sum	17	6	6		0.353		6.000	0.230	13.167	0.230	
sha256sum	17	6	6		0.353		4.667	0.183	11.833	0.183	
sha384sum	17	6	6		0.353		3.333	0.146	18.500	0.146	
sha512sum	17	6	6		0.353		3.333	0.146	18.500	0.146	
shred	27	10	10		0.370		68.600	3.114	69.300	3.114	
shuf	12	4	4		0.333		2.000	0.032	3.750	0.032	
sleep	12	3	3		0.250		2.667	0.042	5.000	0.042	
sort	46	12	11		0.239		5.917	0.299	7.833	0.216	
split	18	6	6		0.333		3.167	0.113	4.333	0.113	
stat	32	10	9		0.281		103.900	0.197	104.600	0.197	
stdbuf	16	5	5		0.312		3.200	0.027	4.600	0.027	
stty	19	5	5		0.263		2.000	0.125	4.600	0.125	
sum	22	8	8		0.364		5.875	0.066	6.750	0.066	
sync	11	3	3		0.273		2.667	0.042	5.000	0.042	
tac	33	19	17		0.515		148.579	0.620	434.053	0.151	
tail	20	8	8		0.400		5.500	0.034	6.375	0.034	
tee	14	4	4		0.286		4.000	0.032	5.750	0.032	
test	12	5	5		0.417		4.200	0.139	4.200	0.139	
timeout	13	5	5		0.385		3.600	0.131	5.000	0.131	
touch	56	23	22		0.393		59.087	0.618	54.174	0.357	
tr	17	4	4		0.235		57.750	0.250	5.750	0.040	
true	9	3	3		0.333		2.667	0.042	5.000	0.042	
truncate	10	3	3		0.300		2.667	0.042	5.000	0.042	
tsort	13	4	4		0.308		11.000	2.282	5.750	0.094	
tty	10	3	3		0.300		2.667	0.042	5.000	0.042	
uname	12	3	3		0.250		2.667	0.042	5.000	0.042	
unexpand	11	3	3		0.273		2.667	0.042	5.000	0.042	
uniq	15	4	4		0.267		2.250	0.157	5.750	0.157	
unlink	12	3	3		0.250		2.667	0.042	5.000	0.042	
uptime	18	8	7		0.389		129.500	0.220	130.375	0.220	
users	12	3	3		0.250		2.667	0.042	5.000	0.042	
vdir	71	32	31		0.437		156.688	5.807	156.906	5.807	
wc	16	6	6		0.375		5455.500	0.378	5456.667	0.378	
who	25	13	13		0.520		1.615	0.024	2.154	0.024	
whoami	12	3	3		0.250		2.667	0.042	5.000	0.042	
yes	12	3	3		0.250		2.667	0.042	5.000	0.042	

TABLE XLVI: Array recovery (compilation = standard)

	Ground truth varnodes	array comparisons	Array varnodes inferred array	as	Array varnodes inferred array	as	Array length (elements) average error	Array length (elements) average error	Array size (bytes) average error	Array size (bytes) average error	size error ratio
[	15	10	10		0.667		15.000	1.379	2.900	0.079	
b2sum	24	30	20		0.833		43.300	21.879	28.633	0.400	

TABLE XLVI: Array recovery (compilation = standard)

	Ground truth varnodes	Array comparisons	Array varnodes inferred array	as inferred array	Array varnodes inferred as fraction	Array length (elements) average error	Array length (elements) average error ratio	Array size (bytes) average error	Array size (bytes) average error ratio	size error
base32	12	8	8		0.667	37.625	5.141	1.875	0.016	
base64	12	9	9		0.750	33.444	4.570	1.667	0.014	
basename	10	7	7		0.700	43.000	5.875	2.143	0.018	
basenc	20	13	13		0.650	42.231	3.164	1.154	0.010	
cat	11	8	8		0.727	53.125	5.141	1.875	0.016	
chcon	18	12	12		0.667	49.083	3.449	4.583	0.032	
chgrp	15	9	9		0.600	58.222	4.601	2.333	0.046	
chmod	19	10	10		0.526	47.600	4.217	3.500	0.117	
chown	16	10	10		0.625	55.800	4.156	2.400	0.056	
chroot	11	8	8		0.727	38.000	5.159	2.250	0.034	
cksum	66	62	50		0.758	738.516	12.144	4245.500	0.315	0.000
comm	22	16	16		0.727	35.875	4.103	3.000	0.103	0.000
cp	40	27	26		0.650	52.630	4.476	3.741	0.078	0.000
csplit	35	30	28		0.800	115.433	2.345	275.300	0.115	0.000
cut	12	8	8		0.667	58.000	5.141	2.875	0.016	
date	63	57	55		0.873	91.842	3.351	39.807	0.175	0.000
dd	34	23	21		0.618	182.913	2.327	172.696	0.110	0.000
df	25	16	16		0.640	120.562	8.072	43.500	1.947	0.000
dir	71	61	60		0.845	135.951	8.784	82.311	3.046	0.000
dircolors	13	9	9		0.692	102.889	6.125	1.667	0.014	
dirname	10	7	7		0.700	34.143	5.875	2.143	0.018	0.000
du	51	41	38		0.745	124.683	2.608	226.756	0.123	0.000
echo	9	6	6		0.667	19.167	1.688	2.500	0.021	
env	18	13	13		0.722	41.769	3.265	3.077	0.111	
expand	13	9	9		0.692	31.556	5.347	1.667	0.014	
expr	33	27	25		0.758	118.593	2.585	305.741	0.108	0.000
factor	37	27	27		0.730	394.889	11.232	2.444	0.112	
false	9	6	6		0.667	19.167	1.688	2.500	0.021	
fmt	12	9	9		0.750	4380.556	8.903	1.667	0.014	
fold	12	8	8		0.667	37.625	5.141	1.875	0.016	
groups	11	8	8		0.727	26.000	5.141	1.875	0.016	
head	18	15	15		0.833	32.000	3.328	5.133	0.128	
hostid	12	7	7		0.583	29.714	5.875	2.143	0.018	
id	14	11	11		0.786	38.909	3.752	1.636	0.025	
join	18	13	13		0.722	32.692	5.548	1.154	0.010	
kill	14	9	9		0.643	34.556	4.628	2.778	0.073	
link	12	7	7		0.583	29.714	5.875	2.143	0.018	
ln	22	13	13		0.591	56.538	4.476	2.385	0.015	
logname	12	7	7		0.583	29.714	5.875	2.143	0.018	
ls	71	61	60		0.845	135.951	8.784	82.311	3.046	0.000
md5sum	16	10	10		0.625	52.600	4.153	2.300	0.053	
mkdir	19	11	11		0.579	34.091	4.061	3.364	0.061	
mkfifo	12	8	8		0.667	35.500	5.208	3.625	0.083	
mknod	12	8	8		0.667	35.500	5.208	3.625	0.083	
mktemp	12	8	8		0.667	48.000	6.016	1.875	0.016	
mv	34	21	20		0.588	36.857	4.326	4.810	0.100	
nice	10	7	7		0.700	34.143	5.875	2.143	0.018	
nl	36	28	26		0.722	125.393	2.385	294.536	0.103	0.000
nohup	13	7	7		0.538	29.714	5.875	2.143	0.018	
nproc	10	7	7		0.700	38.571	5.875	2.143	0.018	
numfmt	20	17	17		0.850	56.882	4.819	1.588	0.015	
od	40	28	28		0.700	31.821	2.884	2.429	0.063	0.000
paste	10	7	7		0.700	43.000	5.875	2.143	0.018	
pathchk	10	7	7		0.700	34.143	5.875	2.143	0.018	
pinky	17	14	14		0.824	33.429	3.452	19.643	0.523	
pr	20	15	14		0.700	133.667	2.928	69.467	0.128	0.000
printenv	10	7	7		0.700	34.143	5.875	2.143	0.018	
printf	17	12	12		0.706	29.167	1.206	19.083	0.123	

TABLE XLVI: Array recovery (compilation = standard)

	Ground truth varnodes	Array comparisons	Array varnodes inferred array	as array	Array varnodes inferred as array fraction	Array length (elements) average error	Array length (elements) average error ratio	Array size (bytes) average error	Array size (bytes) average error ratio	size error
ptx	39	31	29		0.744	119.806	2.481	266.129	0.097	
pwd	10	7	7		0.700	38.571	5.875	2.143	0.018	
readlink	12	8	8		0.667	58.000	5.149	2.875	0.024	
realpath	11	7	7		0.636	74.000	5.875	2.143	0.018	
rm	15	9	9		0.600	61.556	5.681	1.667	0.014	
rmdir	14	10	10		0.714	36.100	4.413	2.300	0.013	
runcon	10	7	7		0.700	51.857	5.875	2.143	0.018	
seq	15	10	10		0.667	32.200	4.413	1.500	0.013	
sha1sum	16	11	11		0.688	48.182	3.807	5.727	0.080	
sha224sum	17	12	12		0.706	61.500	3.781	6.583	0.115	
sha256sum	17	12	12		0.706	60.833	3.758	5.917	0.092	
sha384sum	17	11	11		0.647	48.182	3.807	10.091	0.080	
sha512sum	17	11	11		0.647	48.182	3.807	10.091	0.080	
shred	27	19	19		0.704	71.421	4.850	36.474	1.639	
shuf	12	8	8		0.667	53.125	5.141	1.875	0.016	
sleep	12	7	7		0.583	29.714	5.875	2.143	0.018	
sort	46	27	26		0.565	52.926	2.837	3.481	0.096	
split	18	12	12		0.667	54.917	3.723	2.167	0.056	
stat	32	22	21		0.656	68.591	2.589	47.545	0.089	
stdbuf	16	11	11		0.688	36.273	6.103	2.091	0.012	
stty	19	14	14		0.737	311.143	8.688	1.643	0.045	
sum	22	16	16		0.727	20.438	3.908	3.375	0.033	
sync	11	7	7		0.636	38.571	5.875	2.143	0.018	
tac	33	28	26		0.788	117.036	2.635	294.536	0.103	
tail	20	14	14		0.700	48.000	3.591	4.357	0.064	
tee	14	10	10		0.714	35.600	5.113	2.300	0.013	
test	12	9	9		0.750	16.556	1.522	2.333	0.077	
timeout	13	9	9		0.692	41.444	4.628	2.778	0.073	
touch	56	50	49		0.875	79.260	4.084	24.920	0.164	
tr	17	13	13		0.765	49.154	3.769	1.769	0.012	
true	9	6	6		0.667	19.167	1.688	2.500	0.021	
truncate	10	7	7		0.700	47.429	5.875	2.143	0.018	
tsort	13	8	8		0.615	30.500	6.266	2.875	0.047	
tty	10	7	7		0.700	38.571	5.875	2.143	0.018	
uname	12	8	8		0.667	80.250	9.016	1.875	0.016	
unexpand	11	8	8		0.727	39.375	6.016	1.875	0.016	
uniq	15	12	12		0.800	50.250	5.136	1.917	0.052	
unlink	12	7	7		0.583	29.714	5.875	2.143	0.018	
uptime	18	13	12		0.667	97.077	3.366	80.231	0.136	
users	12	7	7		0.583	29.714	5.875	2.143	0.018	
vdir	71	61	60		0.845	135.951	8.784	82.311	3.046	
wc	16	11	11		0.688	3015.818	4.206	2976.364	0.206	
who	25	19	19		0.760	37.211	2.332	1.474	0.016	
whoami	12	7	7		0.583	29.714	5.875	2.143	0.018	
yes	12	7	7		0.583	29.714	5.875	2.143	0.018	

TABLE XLVII: Array recovery (compilation = debug)

	Ground truth varnodes	Array comparisons	Array varnodes inferred array	as array	Array varnodes inferred as array fraction	Array length (elements) average error	Array length (elements) average error ratio	Array size (bytes) average error	Array size (bytes) average error ratio	size error
[	15	16	15		1.000	0.000	0.000	0.000	0.000	
b2sum	24	25	24		1.000	0.000	0.000	0.000	0.000	
base32	12	13	12		1.000	0.000	0.000	0.000	0.000	
base64	12	12	12		1.000	0.000	0.000	0.000	0.000	

TABLE XLVII: Array recovery (compilation = debug)

	Ground truth array varnodes	Array comparisons	Array varnodes inferred array	as inferred array	as fraction	Array length (elements) average error	Array length (elements) average error ratio	Array size (bytes) average error	Array size (bytes) average error ratio
basename	10	10	10	1.000		0.000	0.000	0.000	0.000
basenc	20	21	20	1.000		0.000	0.000	0.000	0.000
cat	11	12	11	1.000		0.000	0.000	0.000	0.000
chcon	18	18	18	1.000		0.000	0.000	0.000	0.000
chgrp	15	15	15	1.000		0.000	0.000	0.000	0.000
chmod	19	20	19	1.000		0.000	0.000	0.000	0.000
chown	16	16	16	1.000		0.000	0.000	0.000	0.000
chroot	11	11	11	1.000		0.000	0.000	0.000	0.000
cksum	66	67	66	1.000		0.000	0.000	0.000	0.000
comm	22	22	22	1.000		0.000	0.000	0.000	0.000
cp	40	44	39	0.975		0.000	0.000	0.000	0.000
csplit	35	36	35	1.000		6.667	0.026	6.667	0.026
cut	12	12	12	1.000		0.000	0.000	0.000	0.000
date	63	70	63	1.000		31.071	0.100	31.071	0.100
dd	34	37	34	1.000		0.000	0.000	0.000	0.000
df	25	26	25	1.000		24.269	1.156	24.269	1.156
dir	71	75	71	1.000		47.200	0.840	47.200	0.840
dircolors	13	13	13	1.000		0.000	0.000	0.000	0.000
dirname	10	10	10	1.000		0.000	0.000	0.000	0.000
du	51	54	51	1.000		23.259	0.036	23.259	0.036
echo	9	9	9	1.000		0.000	0.000	0.000	0.000
env	18	19	18	1.000		0.000	0.000	0.000	0.000
expand	13	13	13	1.000		0.000	0.000	0.000	0.000
expr	33	33	33	1.000		7.273	0.028	7.273	0.028
factor	37	32	32	0.865		0.000	0.000	0.000	0.000
false	9	9	9	1.000		0.000	0.000	0.000	0.000
fmt	12	12	12	1.000		0.000	0.000	0.000	0.000
fold	12	12	12	1.000		0.000	0.000	0.000	0.000
groups	11	12	11	1.000		0.000	0.000	0.000	0.000
head	18	19	18	1.000		0.000	0.000	0.000	0.000
hostid	12	12	12	1.000		0.000	0.000	0.000	0.000
id	14	17	14	1.000		0.000	0.000	0.000	0.000
join	18	18	18	1.000		0.000	0.000	0.000	0.000
kill	14	14	14	1.000		0.000	0.000	0.000	0.000
link	12	12	12	1.000		0.000	0.000	0.000	0.000
ln	22	23	22	1.000		0.000	0.000	0.000	0.000
logname	12	12	12	1.000		0.000	0.000	0.000	0.000
ls	71	75	71	1.000		47.200	0.840	47.200	0.840
md5sum	16	17	16	1.000		0.000	0.000	0.000	0.000
mkdir	19	20	18	0.947		0.000	0.000	0.000	0.000
mkfifo	12	13	12	1.000		0.000	0.000	0.000	0.000
mknod	12	13	12	1.000		0.000	0.000	0.000	0.000
mktemp	12	13	12	1.000		0.000	0.000	0.000	0.000
mv	34	36	33	0.971		0.000	0.000	0.000	0.000
nice	10	10	10	1.000		0.000	0.000	0.000	0.000
nl	36	36	36	1.000		6.667	0.026	6.667	0.026
nohup	13	13	13	1.000		0.000	0.000	0.000	0.000
nproc	10	10	10	1.000		0.000	0.000	0.000	0.000
numfint	20	20	20	1.000		0.000	0.000	0.000	0.000
od	40	42	40	1.000		0.000	0.000	0.000	0.000
paste	10	10	10	1.000		0.000	0.000	0.000	0.000
pathchk	10	10	10	1.000		0.000	0.000	0.000	0.000
pinky	17	19	17	1.000		11.789	0.046	11.789	0.046
pr	20	21	20	1.000		48.381	0.047	48.381	0.047
printenv	10	10	10	1.000		0.000	0.000	0.000	0.000
printf	17	18	17	1.000		0.000	0.000	0.000	0.000
ptx	39	39	39	1.000		6.154	0.024	6.154	0.024
pwd	10	10	10	1.000		0.000	0.000	0.000	0.000



TABLE XLVII: Array recovery (compilation = debug)

	Ground truth varnodes	Array array comparisons	Array varnodes inferred array	as	Array varnodes inferred array fraction	Array length (elements) average error	Array length (elements) average error ratio	Array size (bytes) average error	Array size (bytes) average error ratio	
readlink	12	12	12		1.000	0.000	0.000	0.000	0.000	
realpath	11	11	11		1.000	0.000	0.000	0.000	0.000	
rm	15	15	15		1.000	0.000	0.000	0.000	0.000	
rmdir	14	15	14		1.000	0.000	0.000	0.000	0.000	
runcon	10	10	10		1.000	0.000	0.000	0.000	0.000	
seq	15	17	15		1.000	0.000	0.000	0.000	0.000	
sha1sum	16	17	16		1.000	0.000	0.000	0.000	0.000	
sha224sum	17	18	17		1.000	0.000	0.000	0.000	0.000	
sha256sum	17	18	17		1.000	0.000	0.000	0.000	0.000	
sha384sum	17	18	17		1.000	0.000	0.000	0.000	0.000	
sha512sum	17	18	17		1.000	0.000	0.000	0.000	0.000	
shred	27	27	27		1.000	23.370	0.036	23.370	0.036	
shuf	12	12	12		1.000	0.000	0.000	0.000	0.000	
sleep	12	12	12		1.000	0.000	0.000	0.000	0.000	
sort	46	50	46		1.000	0.320	0.010	0.320	0.010	
split	18	18	17		0.944	0.000	0.000	0.000	0.000	
stat	32	37	32		1.000	27.459	0.027	27.459	0.027	
stdbuf	16	17	16		1.000	0.000	0.000	0.000	0.000	
stty	19	21	19		1.000	0.000	0.000	0.000	0.000	
sum	22	23	22		1.000	0.000	0.000	0.000	0.000	
sync	11	11	11		1.000	0.000	0.000	0.000	0.000	
tac	33	35	33		1.000	6.857	0.027	6.857	0.027	
tail	20	19	19		0.950	0.000	0.000	0.000	0.000	
tee	14	14	14		1.000	0.000	0.000	0.000	0.000	
test	12	13	12		1.000	0.000	0.000	0.000	0.000	
timeout	13	13	13		1.000	0.000	0.000	0.000	0.000	
touch	56	60	56		1.000	19.317	0.100	19.317	0.100	
tr	17	17	17		1.000	0.000	0.000	0.000	0.000	
true	9	9	9		1.000	0.000	0.000	0.000	0.000	
truncate	10	10	10		1.000	0.000	0.000	0.000	0.000	
tsort	13	13	13		1.000	0.000	0.000	0.000	0.000	
tty	10	10	10		1.000	0.000	0.000	0.000	0.000	
uname	12	13	12		1.000	0.000	0.000	0.000	0.000	
unexpand	11	11	11		1.000	0.000	0.000	0.000	0.000	
uniq	15	15	15		1.000	0.000	0.000	0.000	0.000	
unlink	12	12	12		1.000	0.000	0.000	0.000	0.000	
uptime	18	19	18		1.000	53.474	0.052	53.474	0.052	
users	12	12	12		1.000	0.000	0.000	0.000	0.000	
vdir	71	75	71		1.000	47.200	0.840	47.200	0.840	
wc	16	18	16		1.000	0.000	0.000	0.000	0.000	
who	25	29	25		1.000	0.000	0.000	0.000	0.000	
whoami	12	12	12		1.000	0.000	0.000	0.000	0.000	
yes	12	12	12		1.000	0.000	0.000	0.000	0.000	