APPENDIX A
GENERATION OF TEST CASES FOR SIR PROGRAMS

Each of the SIR programs had an existing pool of test cases. However, these pools were not large enough (consisting of a few thousand test cases per program) to ensure sufficient randomness for our experiments. Therefore, rather than sampling test cases from the existing pools, we used a number of techniques to dynamically generate test cases on demand. Our broad approach for this has some similarities to fuzz testing. We first analyzed the existing test pools to obtain the probability distributions of certain parameters. Then, according to the probability distributions, the concrete values of these parameters could be randomly chosen. We now describe the details of the technique used for each object program.

A.1 `schedule` and `schedule2`

These two programs have four input parameters: three integers representing the number of jobs on the 1st, 2nd, and 3rd priorities, and an input file. To generate inputs we applied the following procedure:

1) Randomly choose the number of input parameters, with the following probabilities: 99% for 3, 0.8% for 2, 0.1% for 1, and 0.1% for 0.
2) Randomly choose whether the total number of jobs should be 0, with the following probabilities: 8% for yes, and 92% for no.
3) If "no" is chosen for 2, choose the value of each input parameter, with a 20% probability of selecting 0, and and 80% probability of selecting each of 1 through 10.
4) Randomly select an input file from the 2151 files in the existing test pool.

A.2 `printtokens` and `printtokens2`

These two programs take a single file as input. To generate inputs we applied the following procedure:

1) Decide on the validity of the input, with a 0.5% probability of generating "two input files"; 0.5% for "one non-existing file"; 99% for "one existing file".
2) If one existing file is chosen as input, randomly choose whether the input file is an original file in the test pool (50% probability) or a file combining two original files in the test pool (50%).
3) If the input file is an original file in the test pool, randomly select one file from the test pool (the number of files in the pool: 4071).
4) If the input file is composed of two original files, randomly select two different files from the test pool and concatenate them.

A.3 `replace`

There are three input parameters for `replace`: strings representing the regular expression (RE) and the replacing string (RS), respectively, and the input file (F). We used the following procedure to generate them:

1) Randomly choose the number of input parameters according to the following probabilities: 97% for 3 (RE, RS, and F), 2.7% for 2 (RE and F), and 0.3% for 1 (F only).
2) For each parameter to be generated, randomly choose an existing input from the existing test pool and extract the relevant input values.

A.4 `tcas`

There are twelve input parameters for `tcas`, each of which is an integer. We used the following procedure to generate inputs:

1) Randomly choose whether the input is from the test pool (with probability 50%) or randomly combined based on the parameters from inputs in the test pool (50%).
2) If the input is from the test pool, randomly select one test case from the test pool (the number of test cases in the pool: 1608).
3) If the input is randomly combined based on the parameters in the test pool, for each input value, select a test case in the pool, extract the input parameter from that pool item, and then combine the selected parameters into a new input.

A.5 `totinfo`

The input for `totinfo` is one file. To generate the input file, we used the following procedure:

1) Randomly choose whether the input file is a file in the original test pool (with probability 50%) or a file combining two original files in the test pool (50%).
2) If the file is to be from the original test pool, randomly select one.
3) If the input file is composed from two files from the test pool, randomly select two different files from the pool and concatenate them.

TABLE A1
Independent and Dependent Categories for `grep`

Independent Category	Dependent Category
NormalChar	Bracket
WordSymbol	Iteration
DigitSymbol	Parentheses
SpaceSymbol	Line
NamedSymbol	Word
AnyChar	Edge
Range	Combine

TABLE A2
Examples of Test Cases Involving Independent Categories for `grep`

Category	Possible Choice	Test Case
NormalChar	NormalAlNum	A
WordSymbol	YesWord	\w
DigitSymbol	NoDigit	\D
SpaceSymbol	NoSpace	\S
NamedSymbol	ALPHA	[:ALPHA:]
AnyChar	Dot	.
Range	NumRange	[1-9]

APPENDIX B
GENERATION OF TEST CASES FOR GREP

For `grep`, we used a generator that was itself based on the categories and choices devised for ART selection.

We first divided the categories into two groups – the independent categories and the dependent categories. The independent group includes all categories that contain elements that can form a regular expression usable as a test case on their own (for instance, a single literal forms a legitimate `grep` regular expression). Dependent categories are those that, without the presence of data that fall into other categories, cannot form an input. Categories 1 through 7 (described fully in Table A6) were classified as independent categories and the rest were classified as dependent. The dependent and independent categories are listed in Table A1.

We next systematically generated random candidate test cases, which were collectively guaranteed to cover each category and choice. For independent categories, this is straightforward: for instance, the "NormalChar" category has a choice "NormalAlNum". To generate a test case that has this choice, a single character from the set containing all letters and digits is generated randomly. For dependent categories, elements from the dependent categories must be combined with an element from an independent category (based on the constraints from the specification), constructed as discussed above, to make a complete, valid test case; for instance, the dependent category "Iteration" could be combined with a "NormalAlNum" character to form a regular expression. Examples of values for each independent category are shown in Table A2, and example combinations of categories including dependent categories are shown in Table A3.

Category "Combine" is a special case: it involves either concatenation or selection between alternatives. When this category is selected, a choice (concatenation or selection) is determined. The procedure described in the paragraphs above is then used to generate the two subsidiary elements that are finally combined in the test case. For example, two subsidiary elements "a" and "b" combined based on concatenation are "ab"; and when combined based on alternation are "a|b".

Note that our test generator does not randomly sample from the entire input domain of `grep`. Instead, only a small subset of the input space is sampled from, as our purpose is to test the regular expression analyzer of grep. We further filtered the randomly generated pool to remove duplicate entries. The final pool contained 171,634 elements.

TABLE A3
Examples of Test Cases Involving Dependent Categories for `grep`. (*Dependent Categories and Their Associated Choices are Italicized*)

Combination of Categories	Possible Combination of Choices	Example of Test Cases
Bracket; NormalChar	*NormalBracket*; NormalAlNum	[A]
Iteration; Range	*Star*; UpcaseRange	[A-Z]*
Parentheses; NormalChar; DigitSymbol	*NormParen*; NormalAlNum; YesDigit	(A\d)
Line; WordSymbol	*BegLine*; YesWord	^\w
Word; DigitSymbol	*EndWord*; NoDigit	\D\>
Edge; Range	*YesEdgeBegEnd*; NumRange	\b[1-9]\b
Combine; *Iteration*; *Parentheses*; NormalChar; Range	*Concatenation*; *Plus*; *NormParen*; NormalAlNum; NumRange	(A[0-9])+

APPENDIX C
FULL CATEGORY-CHOICE DESCRIPTION

Tables A4 to A15 give the details on the categories and choices used for the object programs considered in our study. Note that our categories and choices are mutually exclusive in terms of the inputs that our test case generator is able to actually produce. If the entire input domain of grep was to be considered, several categories in our category-choice definition (for instance, the category NormalChar) would then contain choices which are not mutually exclusive. If necessary, this issue can be resolved by defining an additional choice in each such category, representing the intersection of the two existing choices. For instance, for our category "NormalChar" in Table A6, a "both" choice could be defined. This choice applies to the situation where both the two existing choices "NormalAlNum" and "NormalPunct", would otherwise exist.

APPENDIX D
FULL EXPERIMENTAL RESULTS OF F-MEASURES

In Tables A16 to A29, we include the complete results of F-measures for RT, *ARTmif*, and *ARTsum* on all 14 object programs. In the tables below, F-ratio refers to the ratio between the F-measures of ART and RT, and "sDev" denotes the sample standard deviation for the F-measures.

APPENDIX E
RANKING OF P-MEASURE

Table A30 the complete comparison results of the PMA (P-measure area) for all faults of all 14 object programs. As can be seen, they are similar to the rankings for the F-measure.

TABLE A4
Definition of categories and choices for cal

#	Category	Choice
1	number of parameters	0
		1
		2
2	month	< 1 or > 12
		≥ 1 or ≤ 12
3	year	< 1 or > 9999
		leap year
		non-leap year

TABLE A5
Definition of categories and choices for comm

#	Category	Choice
1	number of parameters	< 3
		3
		> 3
2	option 1	exist
		not exist
3	option 2	exist
		not exist
4	option 3	exist
		not exist
5	bad option	exist
		not exist
6	file 1	not exist
		contents sorted
		contents unsorted
7	file 2	not exist
		contents sorted
		contents unsorted
8	common lines	exist
		not exist

TABLE A6
Definition of categories and choices for `grep`

#	Category	Choice
1	NormalChar - presence of any literal character	NormalAlNum - presence of any alphabetic or numerical literal (for instance "A", "z", or "5")
		NormalPunct - presence of any punctuation character (such as ":")
2	WordSymbol - presence of "word" or "non-word" metacharacters	YesWord - "\w" present
		NoWord - "\W" present
3	DigitSymbol - presence of "digit" or "non-digit" metacharacters	YesDigit - "\d" present
		NoDigit - "\D" present
4	SpaceSymbol - presence of any "whitespace" or "non-space" metacharacters	YesSpace - "\s" present
		NoSpace - "\S" present
5	NamedSymbol - presence of a symbol from a character group	ALPHA - presence of [:ALPHA:]
		UPPER - presence of [:UPPER:]
		LOWER - presence of [:LOWER:]
		DIGIT - presence of [:DIGIT:]
		XDIGIT - presence of [:XDIGIT:]
		SPACE - presence of [:SPACE:]
		PUNCT - presence of [:PUNCT:]
		ALNUM - presence of [:ALNUM:]
		PRINT - presence of [:PRINT:]
		GRAPH - presence of [:GRAPH:]
		CNTRL - presence of [:CNTRL:]
		BLANK - presence of [:BLANK:]
6	AnyChar - presence of the "." metacharacter (matches any character)	Dot - dot (".") present
7	Range - presence of a pattern representing a character range	NumRange - number range present (for example "[1-7]")
		UpcaseRange - uppercase letter range present (for example "[C-G]")
		LowcaseRange - lowercase letter range present (such as "[s-w]")
8	Bracket - presence of patterns encompassed by [] or [ˆ]	NormalBracket - "[]" pattern present
		CaretBracket - [ˆ] pattern present
9	Iteration - presence of patterns that contain iterator symbols	Qmark - presence of the question mark metacharacter ("?"), which matches 0 or 1 iteration
		Star - presence of the star metacharacter ("*"), matching zero or more iterations
		Plus - presence of the plus metacharacter("+"), matching one or more iterations
		Repminmax - presence of min-max repetition form: for example, "{2, 3}" matches lines containing "aa" or "aaa"
10	Parentheses - used to group patterns for repetition, also "backreferencing"	NormParen - presence of a pattern surrounded by parentheses
		Backref - presence of a pattern with normal parentheses and a back reference
11	Line - presence of special characters relating to line boundaries	BegLine - presence of ("ˆ") (matches beginning of line)
		EndLine - presence of ("$") (matches end of line)
		BegEndLine - presence of ("ˆ"..."$") (matches beginning and end of line)
12	Word - presence of sequences that match word beginnings or ends	BegWord - presence of a ("\<") metacharacter (matches word beginning)
		EndWord - presence of a ("\>") metacharacter (matches word end)
		BegEndWord - presence of a ("\<" ... "\>") pattern (matches word end)

TABLE A6
Definition of categories and choices for `grep` (continued)

#	Category	Choice
13	Edge - presence of sequences that match word boundaries	YesEdgeBeg - presence of a "\b" metacharacter (sequence must lie on a word edge at the beginning - for example "\babc" matches "abcde" but not "xabc")
		YesEdgeEnd - presence of the "\b" metacharacter (sequence must lie on a word edge at the end - for example "abc\b" matches "12abc" but not "abc12")
		YesEdgeBegEnd - presence of "\b" ... "\b" pattern - sequence must lie on a word edge at the beginning and the end (for example "\babc\b" matches "abc" only)
		NoEdgeBeg - presence of "\B" metacharacter - sequence must not lie on a word edge at the beginning (for example, "\Babc" matches "xabce" but not "abcde").
		NoEdgeEnd - presence of "\B" metacharacter - sequence must not lie on a word edge at the end (for example, "abc\B" matches "xabce" but not "xabc").
		NoEdgeBegEnd - presence of "\B" ... "\B" - sequence must not lie on a word edge at the beginning and the end (for example, "\Babc\B" matches "xabce" but not "abcdeabc").
14	Combine - combining multiple patterns	Concatenation - presence of a sequence of tokens (which must all appear in sequence in the text to match - for example, "ab" matches "abx" or "cab" but not "aaa", "axb", or "bax")
		Alternative - presence of two tokens separated by the "|" metacharacter (presence of either token will result in a match - for instance "a|b" matches "ast" or byz")

TABLE A7
Definition of categories and choices for `look`

#	Category	Choice
1	number of parameters	0
		1
		2
		3
		> 3
2	input	default dictionary (input file name does not exist)
		input file exists
		invalid input file name
3	option d	exist
		not exist
4	option f	exist
		not exist
5	bad option	exist
		not exist
6	search string	exist and length < 250
		exist and length ≥ 250
		not exist
7	search string is found	yes
		no

TABLE A8
Definition of categories and choices for `printtokens` and `printtokens2`

#	Category	Choice
1	NumOfInputs - number of parameters of the input	Input=0 - an input has no parameters (an empty string input)
		Input=1 - an input has one parameter (input file name)
2	FileExist - presence of the file input	Yes - the file exists
		No - the file does not exist
3	HasEmptyString - presence of an empty string in the file input	Yes - an empty string present
		No - no empty string present
4	HasStringLength80 - presence of a string with length equal to 80 in the file input	Yes - a string with length equal to 80 present
		No - no string with length equal to 80 present
5	HasStringLengthLess80 - presence of a non-empty string with length less than 80 in the file input	Yes - a non-empty string with length less than 80 present
		No - no non-empty string with length less than or equal to 80 present
6	HasStringLengthGreater80 - presence of a string with length greater than 80 in the file input	Yes - a string with length greater than 80 present
		No - no string with length greater than 80 present
7	HasStringWithoutDoubleQuotes - presence of a string having no double quotes in the file input	Yes - a string having no double quotes present
		No - there are no strings without double quotes
8	HasStringWithEvenDoubleQuotes - presence of a string enclosed by a pair of double quotes in the file input	Yes - a string enclosed by a pair of double quotes present
		No - no strings enclosed by a pair of double quotes present
9	HasStringWithOddDoubleQuote - presence of a string not enclosed by a pair of double quotes in the file input	Yes - a string not enclosed by a pair of double quotes present
		No - no strings not enclosed with a pair of double quotes are present
10	BlankInsideEnclosedDoubleQuote - presence a blank string enclosed by a pair of double quotes in file input	Yes - a blank string enclosed by a pair of double quotes present
		No - no blank string enclosed by a pair of double quotes
11	Has# - presence of # in a string in the file input	Yes - # present in any string in the file input
		No - no # present in any string in the file input
12	HasCharAfter# - presence of any characters after # in the file input	Yes - a string with a character after # present
		No - no string with a character after # present
13	HasLambda - presence of keyword "lambda" in the file input	Yes - keyword "lambda" present
		No - keyword "lambda" not present
14	HasAnd - presence of keyword "and" in the file input	Yes - keyword "and" present
		No - keyword "and" not present
15	HasIf - presence of keyword "if" in the file input	Yes - keyword "if" present
		No - keyword "if" not present
16	HasOr - presence of keyword "or" in the file input	Yes - keyword "or" present
		No - keyword "or" not present
17	HasXor - presence of keyword "xor" in the file input	Yes - keyword "xor" present
		No - keyword "xor" not present
18	HasStandAloneAlphaNum - presence of alphanumeric outside double quotes and not after # in the file input	Yes - an alphanumeric character outside double quotes and before # is present
		No - no alphanumeric character outside double quotes and before a# is present
19	HasLParan - presence of left parenthesis in the file input	Yes - left parenthesis present
		No - left parenthesis not present
20	HasRParan - presence of right parenthesis in the file input	Yes - right parenthesis present
		No - right parenthesis not present
21	HasLBracket - presence of left bracket in the file input	Yes - left bracket present
		No - left bracket not present

TABLE A8
Definition of categories and choices for `printtokens` and `printtokens2` (continued)

#	Category	Choice
22	HasRBracket - presence of right bracket in the file input	Yes - right bracket present
		No - right bracket not present
23	HasQuote - presence of single quote in the file input	Yes - single quote present
		No - single quote not present
24	HasBackQuote - presence of back quote in the file input	Yes- back quote bracket present
		No - back quote not present
25	HasComma - presence of comma in the file input	Yes - comma present
		No - comma not present
26	HasGreaterEqual - presence of (>=) in the file input	Yes - (>=) present
		No - (>=) not present
27	HasSpace - presence of space in the file input	Yes - space present
		No - space not present
28	HasOtherChar - presence of any characters in the file input not included in previous categories	Yes - other characters present
		No - no such characters present

TABLE A9
Definition of categories and choices for `replace`

#	Category	Choice
1	NumOfInputParameters - Number of parameters of the input	Input=0 - an input has no parameters (an empty string input)
		Input=1 - an input has one parameter (Regular Expression parameter)
		Input=2 - an input has two parameters (Regular Expression and Replacing String parameters)
		Input=3 - an input has three parameters (Regular Expression, Replacing String, and input file name (containing searched strings to be replaced) parameter)
2	RE_ESC- presence of escape symbol (@) in the regular expression parameter	HasESC - escape symbol present
		NoESC - escape symbol not present
3	RE_BOL - presence of Beginning of Line symbol (%) as a metacharacter	HasMetacharBOL - Beginning of Line symbol present as metacharacter
		NoMetacharBOL - Beginning of Line symbol not present as metacharacter
4	RE_EOL - presence of End of Line symbol ($) as a metacharacter	HasMetacharEOL - End of Line symbol present as metacharacter
		No MetacharEOL - End of Line symbol not present as metacharacter
5	RE_? - presence of symbol ? as a metacharacter	HasMetachar? - symbol ? present as metacharacter
		NoMetachar? - symbol ? not present as metacharacter
6	RE_* - presence of symbol * as a metacharacter	HasMetachar* - symbol * present as metacharacter
		NoMetachar* - symbol * not present as metacharacter
7	RE_EnumCharSet - presence of enumeration type of character set	HasEnumCharSet - enumeration type character set present
		NoEnumCharSet - enumeration type character set not present
8	RE_RangeCharSet - presence of range type of character set	HasRangeCharSet - range type character set present
		NoRangeCharSet - range type character set not present

TABLE A9
Definition of categories and choices for `replace` (continued)

#	Category	Choice
9	RE_MixCharSet - presence of both enumeration and range type of character set	HasMixCharSet - both enumeration and range type of character set present
		NoMixCharSet - enumeration and range type not both present
10	RE_MetacharNegate - presence of negate symbol [^] as metacharacter	HasMetacharNegate - negate symbol present as metacharacter
		NoMetacharNegate - Negate symbol not present as metacharacter
11	RE_MetacharDash - presence of dash symbol [-] as metacharacter in the range enumeration set	HasMetacharDash - dash symbol [-] present as metacharacter in the range enumeration set
		NoMetacharDash - dash symbol [-] not present as metacharacter in the range enumeration set
12	RE_MetacharTab - presence of metacharacter tab symbol (@t) in the regular expression	HasMetacharTab - tab symbol present as metacharacter
		NoMetacharTab - tab symbol not present as metacharacter
13	RE_MetacharNewLine - presence of metacharacter new-line symbol (@n)	HasMetacharNewLine - new-line symbol present as metacharacter
		NoMetacharNewLine - new-line not present as metacharacter
14	RE_Length - determine the length of the regular expression	$\leq$MAXSTR - the length of the non-empty regular expression is less or equal to a pre-determined constant MAXSTR
		>MAXSTR - the length of the non-empty regular expression is greater than a pre-determined constant MAXSTR
		= 0 - the length of the regular expression is 0 (empty string)
15	RS_Esc - presence of escape symbol (@) in the replacing string parameter	HasESC - escape symbol present
		NoESC - escape symbol not present
16	RS_& - presence of symbol & as a metacharacter in the replacing string parameter	HasMetachar& - symbol & present as metacharacter
		NoMetachar& - symbol & not present as metacharacter
17	RS_MetacharTab - presence of metacharacter tab symbol (@t) in the replacing string parameter	HasMetacharTab - tab symbol present as metacharacter
		NoMetacharTab - tab symbol not present as metacharacter
18	RS_MetacharNewLine - presence of metacharacter new line symbol (@n) in the replacing string parameter	HasMetacharNewLine - new line symbol present as metacharacter
		NoMetacharNewLine - new line symbol not present as metacharacter
19	RS_Length - Classifying the length of the replacing string parameter	$\leq$MAXSTR - the length of the non-empty replacing string is less or equal to a pre-determined constant MAXSTR
		>MAXSTR - the length of the non-empty replacing string is greater than a pre-determined constant MAXSTR
		= 0 - the length of the replacing string is 0 (empty string)
20	F_EndStr - presence of end string character in the file referred by the third parameter of an input	HasEndStr - end string character present in the file
		NoEndStr - end string character not present in the file
21	F_NewLine - presence of new line character in the file referred by the third parameter of an input	HasEndStr - new line character present in the file
		NoEndStr - new line character not present in the file

TABLE A9
Definition of categories and choices for `replace` (continued)

#	Category	Choice
22	F_String≤MAXSTR - presence of a string shorter than or equal in length to MAXSTR in the file referred by the third input parameter	HasString≤MAXSTR - at least a string with length less or equal to MAXSTR string present in the file
		NoString≤MAXSTR - no string with length less or equal to MAXSTR string present in the file
23	F_String>MAXSTR - presence a string longer than MAXSTR string in the file referred by the third parameter of an input	HasString>MAXSTR - at least a string with length greater than MAXSTR string present in the file
		NoString>MAXSTR - no string with length equal greater than MAXSTR string present in the file
24	F_EmptyString - presence of empty string in the file referred by the third parameter of an input	HasEmptyString - an empty string present in the file
		NoEmptyString - no empty string present in the file

TABLE A10
Definition of categories and choices for `schedule` and `schedule2`

#	Category	Choice
1	CorrectNumberOfInputParameters - number of parameters of the input	Input=3 - an input has three parameters
		Input≠3 - an input does not have three parameters
2	TotalNumberInitialJobsIn -AllPrioQueues - the total number of initial processes	Tot=0 - the total is zero
		Tot≠0 - the total is not zero
3	InvalidInputInitialJobsInFirstPrioQueue - presence of an invalid input in the first parameter	True - There is an invalid input in the first parameter
		False - There is no invalid input in the first parameter
4	NumberOfInitialJobsInFirstPrioQueue - the number of processes in the first parameter	Num=0 - the number of processes in the first parameter is 0
		Num>0 - the number of processes in the first parameter is > 0
		Num<0 - the number of processes in the first parameter is < 0
5	InvalidInputInitialJobsInSecondPrioQueue - presence of an invalid input in the second parameter	True - There is an invalid input in the second parameter
		False - There is no invalid input in the second parameter
6	NumberOfInitialJobsInSecondPrioQueue - the number of processes in the second parameter	Num=0 - the number of processes in the second parameter is 0
		Num>0 - the number of processes in the second parameter is > 0
		Num<0 - the number of processes in the second parameter is < 0
7	InvalidInputInitialJobsInThirdPrioQueue - presence of an invalid input in the third parameter	True - There is an invalid input in the third parameter
		False - There is no invalid input in the third parameter
8	NumberOfInitialJobsInThirdPrioQueue - the number of processes in the third parameter	Num=0 - the number of processes in the third parameter is 0
		Num>0 - the number of processes in the third parameter is > 0
		Num<0 - the number of processes in the third parameter is < 0
9	FileExist - presence of the input file	True - The file is present
		False - The file is not present
10	NumberOfJobCommandsGivenInFile - the number of commands listed in the input file	Num=0 - the number of job commands is 0
		Num>0 - the number of job commands is > 0

TABLE A10
Definition of categories and choices for `schedule` and `schedule2` (continued)

#	Category	Choice
11	InvalidContent - presence of invalid contents in the input file	True - There is at least an invalid content
		False - There is no invalid content
12	ContainNewJob - presence of NEW JOB command in the input file	True - The NEW JOB command is present in the input file
		False - The NEW JOB command is not present in the input file
13	ContainUpgradePrio - presence of UPGRADE PRIO command in the input file	True - The UPGRADE PRIO command is present in the input file
		False - The UPGRADE PRIO command is not present in the input file
14	ContainBlock - presence of BLOCK command in the input file	True - The BLOCK command is present in the input file
		False - The BLOCK command is not present in the input file
15	ContainUnBlock - presence of UNBLOCK command in the input file	True - The UNBLOCK command is present in the input file
		False - The UNBLOCK command is not present in the input file
16	ContainQuantumExpire - presence of QUANTUM EXPIRE command in the input file	True - The QUANTUM EXPIRE command is present in the input file
		False - The QUANTUM EXPIRE command is not present in the input file
17	ContainFinish - presence of FINISH command in the input file	True - The FINISH command is present in the input file
		False - The FINISH command is not present in the input file
18	ContainFlush - presence of FLUSH command in the input file	True - The FLUSH command is present in the input file
		False - The FLUSH command is not present in the input file
19	ContainNewJobWithoutPrio - presence of NEW JOB without priority parameter in the input file	True - The NEW JOB command without priority parameter is present in the input file
		False - The NEW JOB command without priority parameter is not present in the input file
20	ContainNewJobWithPrio $>$ MAXPRIO - presence of NEW JOB with priority parameter $>$ MAXPRIO in the input file	True - The NEW JOB command with priority parameter $>$ MAXPRIO is present in the input file
		False - The NEW JOB command with priority parameter $>$ MAXPRIO is not present in the input file
21	ContainNewJobWith $0 <$ Prio $\leq$ MAXPRIO - presence of NEW JOB with priority parameter > 0 and $\leq$ MAXPRIO in the input file	True - The NEW JOB command with priority parameter > 0 and $\leq$ MAXPRIO is present in the input file
		False - The NEW JOB command with priority parameter > 0 and $\leq$ MAXPRIO is not present in the input file
22	ContainNewJobWithPrio ≤ 0 - presence of NEW JOB with priority parameter ≤ 0 in the input file	True - The NEW JOB command with priority parameter ≤ 0 is present in the input file
		False - The NEW JOB command with priority parameter ≤ 0 is not present in the input file
23	ContainUpgradePrioWithoutPrio - presence of UPGRADE PRIO without priority parameter in the input file	True - The UPGRADE PRIO command without priority parameter is present in the input file
		False - The UPGRADE PRIO command without priority parameter is not present in the input file
24	ContainUpgradePrioWithPrio $>$ MAXPRIO - presence of UPGRADE PRIO with priority parameter $>$ MAXPRIO in the input file	True - The UPGRADE PRIO command with priority parameter $>$ MAXPRIO is present in the input file
		False - The UPGRADE PRIO command with priority parameter $>$ MAXPRIO is not present in the input file

TABLE A10
Definition of categories and choices for `schedule` and `schedule2` (continued)

#	Category	Choice
25	ContainUpgradePrioWith0 < Prio ≤ MAXPRIO - presence of UPGRADE PRIO with priority parameter > 0 and ≤ MAXPRIO in the input file	True - The UPGRADE PRIO command with priority parameter > 0 and ≤ MAXPRIO is present in the input file
		False - The UPGRADE PRIO command with priority parameter > 0 and ≤ MAXPRIO is not present in the input file
26	ContainUpgradePrioWithPrio ≤ 0 - presence of UPGRADE PRIO with priority parameter ≤ 0 in the input file	True - The UPGRADE PRIO command with priority parameter ≤ 0 is present in the input file
		False - The UPGRADE PRIO command with priority parameter ≤ 0 is not present in the input file
27	ContainUpgradePrioWithoutRatio - presence of UPGRADE PRIO without ratio parameter in the input file	True - The UPGRADE PRIO command without ratio parameter is present in the input file
		False - The UPGRADE PRIO command without ratio parameter is not present in the input file
28	ContainUpgradePrioWithRatio > 1 - presence of UPGRADE PRIO with ratio parameter > 1 in the input file	True - The UPGRADE PRIO command with ratio parameter > 1 is present in the input file
		False - The UPGRADE PRIO command with ratio parameter > 1 is not present in the input file
29	ContainUpgradePrioWith0 < Ratio ≤ 1 - presence of UPGRADE PRIO with ratio parameter > 0 and ≤ 1 in the input file	True - The UPGRADE PRIO command with ratio parameter > 0 and ≤ 1 is present in the input file
		False - The UPGRADE PRIO command with ratio parameter > 0 and ≤ 1 is not present in the input file
30	ContainUpgradePrioWithRatio≤0 - presence of UPGRADE PRIO with ratio parameter ≤ 0 in the input file	True - The UPGRADE PRIO command with ratio parameter ≤ 0 is present in the input file
		False - The UPGRADE PRIO command with ratio parameter ≤ 0 is not present in the input file
31	ContainUnblockWithoutRatio - presence of UNBLOCK without ratio parameter in the input file	True - The UNBLOCK command without ratio parameter is present in the input file
		False - The UNBLOCK command without ratio parameter is not present in the input file
32	ContainUnblockWithRatio>1 - presence of UNBLOCK with ratio parameter > 1 in the input file	True - The UNBLOCK command with ratio parameter > 1 is present in the input file
		False - The UNBLOCK command with ratio parameter > 1 is not present in the input file
33	ContainUnblockWith0<Ratio≤1 - presence of UNBLOCK with ratio parameter > 0 and ≤ 1 in the input file	True - The UNBLOCK command with ratio parameter > 0 and ≤ 1 is present in the input file
		False - The UNBLOCK command with ratio parameter > 0 and ≤ 1 is not present in the input file
34	ContainUnblockWithRatio≤0 - presence of UNBLOCK with ratio parameter ≤ 0 in the input file	True - The UNBLOCK command with ratio parameter ≤ 0 is present in the input file
		False - The UNBLOCK command with ratio parameter ≤ 0 is not present in the input file

TABLE A11
Definition of categories and choices for `sort`

#	Category	Choice
1	number of parameters	0
		≥ 1
2	valid input file	exist
		not exist
3	invalid input file	exist
		not exist
4	option b	exist
		not exist
5	option d	exist
		not exist
6	option f	exist
		not exist
7	option i	exist
		not exist
8	option c	exist
		not exist
9	option m	exist
		not exist
10	option n	exist
		not exist
11	option o	exist
		not exist
12	option t	exist
		not exist
13	option T	exist
		not exist
14	option r	exist
		not exist
15	option u	exist
		not exist
16	option . (DOT)	exist
		not exist
17	bad option	exist
		not exist
18	start position	exist
		not exist
19	end position	exist
		not exist
20	the number of keys	< 10
		≥ 10
21	line longer than 2048	exist
		not exist

TABLE A12
Definition of categories and choices for `spline`

#	Category	Choice
1	number of parameters	0
		≥ 1
2	input	input from screen
		input file exists
		invalid input
3	option a	exist
		not exist
4	option k	exist
		not exist
5	option n	exist
		not exist
6	option p	exist
		not exist
7	option x	exist
		not exist
8	bad option	exist
		not exist
9	number of input data	< 3
		≥ 3 and ≤ 1000
		> 1000
10	input data are monotonic	yes
		no

TABLE A13
Definition of categories and choices for `tcas`

#	Category	Choice
1	Correct_Number_of_Input_Parameters	$= 12$
		$\neq 12$
2	Invalid_Cur_Vertical_Sep_INPUT	TRUE
		FALSE
3	Vertical_Sep_Degree	$>$ MAXALTDIFF
		$\leq$ MAXALTDIFF and $\geq$ MINSEP
		$<$ MINSEP
4	Invalid_High_Confidence_INPUT	TRUE
		FALSE
5	High_Confidence	TRUE
		FALSE
6	Invalid_Two_of_Three_Reports_Valid_INPUT	TRUE
		FALSE
7	Is_Report_Valid	TRUE
		FALSE
8	Invalid_Own&Other_Tracked_Alt_INPUT	TRUE
		FALSE

TABLE A13
Definition of categories and choices for `tcas` (continued)

#	Category	Choice
9	Above_or_Below_Treat	Own_Tracked_Alt < Other_Tracked_Alt
		Own_Tracked_Alt > Other_Tracked_Alt
10	Invalid_Own_Tracked_Alt_Rate_INPUT	TRUE
		FALSE
11	Tracked_Alt	≤ OLEV
		> OLEV
12	Invalid_Alt_Layer_Value_INPUT	TRUE
		FALSE
13	Adequate_Separation_Level	< 0
		= 0
		= 1
		= 2
		= 3
		> 3
14	Invalid_Up_Separation_INPUT	TRUE
		FALSE
15	Up_Separation_Threshold	< 400
		≥ 400 and < 500
		≥ 500 and < 640
		≥ 640 and < 740
		≥ 740
16	Invalid_Down_Separation_INPUT	TRUE
		FALSE
17	Down_Separation_threshold	< 400
		≥ 400 and < 500
		≥ 500 and < 640
		≥ 640 and < 740
		≥ 740
18	Up_Preference	Down_Separation < Up_Separation
		Up_Separation ≤ Down_Separation < Up_Separation + NOZCROSS
		Down_Separation ≥ Up_Separation + NOZCROSS
19	Invalid_Other_RAC_INPUT	TRUE
		FALSE
20	Clear_Intention	= NO_INTENT
		≠ NO_INTENT
21	Invalid_Other_Capability_INPUT	TRUE
		FALSE
22	TCAS_Equipped	TRUE
		FALSE
23	Invalid_Climb_Inhibit_INPUT	TRUE
		FALSE
24	Climb_Inhibit	TRUE
		FALSE

TABLE A14
Definition of categories and choices for `totinfo`

#	Category	Choice
1	Correct_number_of_input_parameters	$= 0$
		≥ 1
2	File_Contain_BlankLine	Yes
		No
3	File_Contain_Comment	Yes
		No
4	File_Contain_Invalid_r_Input	Yes
		No
5	File_Contain_Invalid_c_Input	Yes
		No
6	File_Contain_r×c>MAXTBL	Yes
		No
7	File_Contain_r×c≤MAXTBL	Yes
		No
8	File_Contain_r_Extremely_Big	Yes
		No
9	File_Contain_r>1	Yes
		No
10	File_Contain_r≤1	Yes
		No
11	File_Contain_c_Extremely_Big	Yes
		No
12	File_Contain_c>1	Yes
		No
13	File_Contain_c≤1	Yes
		No
14	File_Contain_Table(s)_without_Input_r	Yes
		No
15	File_Contain_Table(s)_without_Input_c	Yes
		No
16	File_Contain_Table(s)_Size_Not_Equal_r×c	Yes
		No
17	File_Contain_Table(s)_Size_Equal_r×c	Yes
		No
18	File_Contain_Table(s)_with_Invalid_Cell(s)	Yes
		No
19	File_Contain_Table(s)_with_All_Cells_Valid	Yes
		No
20	File_Contain_Table(s)_with_Negative_Cell(s)	Yes
		No
21	File_Contain_Table(s)_with_All_Cells_Zero	Yes
		No

TABLE A15
Definition of categories and choices for `uniq`

#	Category	Choice
1	input	input from screen
		input file exists
		invalid input
2	option	u
		d
		c
		not exist
3	input contents sorted	yes
		no
4	fields	exist
		not exist
5	letters	exist
		not exist
6	duplicate lines	exist
		not exist
7	blank lines	exist
		not exist

TABLE A16
F-measure data on `cal`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	163.92	159.60	39.50	24.10%	38.60	21.23	12.95%	16.70
2	41.72	39.66	11.19	26.82%	9.27	10.51	25.19%	8.74
3	15.91	15.85	8.75	55.02%	7.69	9.26	58.18%	7.42
4	159.13	158.54	94.32	59.27%	91.36	95.73	60.16%	96.15
5	10.13	9.88	6.35	62.74%	4.71	6.89	68.09%	5.99
6	27.41	26.97	9.05	33.02%	8.07	6.95	25.37%	5.05
7	159.15	165.91	59.78	37.56%	59.69	35.38	22.23%	33.34
8	23.56	23.19	7.30	31.00%	5.59	5.78	24.54%	3.95
9	20.45	19.81	13.30	65.00%	13.01	9.94	48.62%	8.76
10	23.69	23.25	15.53	65.54%	15.13	11.25	47.48%	10.14
11	23.34	22.22	11.95	51.21%	10.80	11.19	47.95%	9.84

TABLE A17
F-measure data on `comm`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	125.55	123.89	46.37	36.93%	43.80	47.94	38.19%	38.94
2	31.22	31.09	7.97	25.52%	7.19	6.40	20.51%	5.24
3	186.74	181.12	81.65	43.72%	77.98	81.65	43.72%	77.98
4	18.15	17.43	5.01	27.61%	4.01	4.49	24.72%	3.19
5	12.70	11.81	4.59	36.14%	3.51	4.73	37.27%	3.88
6	19.45	19.54	4.84	24.89%	3.56	4.48	23.03%	2.92
7	10.66	10.41	4.21	39.51%	3.11	4.50	42.17%	3.62
8	21.26	20.44	5.65	26.58%	4.83	5.08	23.91%	3.90
9	13.04	12.30	4.82	36.98%	3.76	5.03	38.53%	4.17
10	63.71	62.17	26.67	41.86%	26.22	26.73	41.96%	26.35
11	93.37	90.24	40.08	42.92%	38.09	40.08	42.93%	38.08
12	35.62	34.28	10.06	28.24%	9.07	8.35	23.44%	6.86
13	194.45	190.52	56.72	29.17%	55.56	40.03	20.59%	37.35
14	42.59	41.20	12.70	29.82%	12.32	10.19	23.93%	8.52
15	149.35	147.47	40.80	27.32%	39.90	32.25	21.59%	30.00
16	26.37	26.28	10.15	38.48%	9.05	14.01	53.13%	14.58
17	45.94	44.15	11.03	24.00%	9.47	10.80	23.51%	8.92
18	36.69	36.21	12.91	35.18%	11.73	15.04	40.98%	15.35
19	75.13	73.67	27.37	36.43%	26.01	45.67	60.79%	47.69
20	11.52	10.66	4.23	36.68%	3.05	4.22	36.63%	3.35
21	147.43	150.74	24.77	16.80%	23.01	17.51	11.88%	15.20
22	143.67	148.86	22.63	15.75%	22.13	16.89	11.75%	15.31
23	10.41	10.06	4.23	40.58%	3.10	4.55	43.71%	3.59
24	12.05	11.08	4.41	36.59%	3.30	4.64	38.51%	3.73
25	26.59	26.28	9.65	36.28%	9.31	10.09	37.94%	9.59
26	10.45	9.48	3.55	33.95%	2.39	3.55	33.95%	2.37
27	73.98	77.57	12.18	16.47%	10.90	9.54	12.89%	7.83

TABLE A18
F-measure data on `grep`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	49.54	48.51	17.72	35.77%	15.05	21.03	42.46%	20.27
2	14.85	14.28	6.18	41.63%	4.58	6.17	41.54%	5.05
3	207.31	209.05	78.01	37.63%	75.23	85.38	41.19%	82.45
4	858.96	862.44	1844.73	214.76%	1163.69	235.39	27.40%	224.52
5	474.26	469.57	154.28	32.53%	147.54	200.21	42.22%	202.59
6	650.99	663.96	215.30	33.07%	211.32	290.47	44.62%	286.39
7	14.40	14.01	6.13	42.55%	4.55	6.00	41.65%	4.79
8	277.52	269.52	94.73	34.14%	87.00	121.81	43.89%	118.95
9	14.89	14.34	6.20	41.65%	4.60	6.19	41.57%	5.03
10	463.90	459.89	156.62	33.76%	148.51	206.06	44.42%	209.24
11	35.75	36.97	16.44	45.98%	14.35	15.56	43.54%	14.48
12	22.20	21.62	19.20	86.47%	20.34	9.58	43.16%	8.86
13	15.34	14.72	6.64	43.27%	5.19	6.47	42.18%	5.20
14	14.88	14.26	6.21	41.72%	4.59	6.19	41.59%	4.94
15	46.46	44.69	49.70	106.98%	52.52	25.39	54.65%	26.72
16	36.47	35.50	13.95	38.26%	12.35	16.03	43.96%	14.77
17	34.90	34.19	46.41	132.95%	52.68	15.85	45.40%	15.15
18	34.18	33.27	13.07	38.25%	10.88	14.24	41.66%	12.79
19	59.68	58.03	22.25	37.29%	20.07	25.58	42.85%	24.93
20	2.23	1.66	2.03	91.42%	1.35	1.93	86.86%	1.19

TABLE A19
F-measure data on `look`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	10.01	9.87	5.49	54.83%	3.78	5.81	58.08%	3.89
2	12.93	12.29	6.05	46.78%	4.04	6.22	48.11%	4.13
3	13.78	13.03	6.23	45.18%	4.16	6.22	45.13%	4.08
4	47.37	47.22	79.45	167.70%	82.65	49.08	103.61%	48.09
5	11.24	10.68	5.83	51.83%	4.13	5.90	52.50%	3.89
6	15.89	15.68	8.98	56.53%	7.34	8.77	55.18%	6.98
7	12.00	11.46	5.90	49.16%	4.08	6.10	50.80%	4.16
8	10.81	10.06	5.23	48.40%	3.21	13.33	123.31%	9.53
9	11.94	11.62	5.89	49.30%	4.17	6.21	51.98%	4.16
10	10.67	10.38	5.66	52.99%	3.86	5.81	54.48%	3.91
11	12.78	12.17	6.02	47.11%	4.14	6.21	48.59%	4.15
12	14.87	14.81	8.87	59.65%	7.22	8.70	58.49%	6.96
13	38.47	38.21	22.66	58.90%	21.77	18.56	48.24%	15.04
14	17.70	17.02	8.21	46.40%	6.17	8.59	48.53%	6.56
15	45.94	46.58	84.34	183.59%	85.76	50.35	109.60%	49.23
16	14.91	14.15	6.20	41.60%	4.02	6.44	43.22%	4.13
17	13.71	13.76	8.56	62.41%	6.82	8.54	62.27%	6.89
18	63.03	66.53	116.55	184.92%	120.60	77.18	122.46%	76.29
19	48.07	46.98	23.62	49.14%	22.22	20.11	41.83%	16.16
20	37.71	38.62	70.71	187.53%	71.99	64.08	169.94%	66.09
21	46.63	48.60	87.96	188.65%	87.25	71.15	152.60%	74.05
22	192.94	193.43	320.25	165.98%	320.13	370.06	191.80%	383.64
23	21.63	21.02	9.67	44.68%	8.08	9.32	43.08%	7.15
24	10.72	9.84	7.67	71.54%	6.37	7.84	73.19%	6.29
25	194.06	203.12	380.96	196.31%	391.12	453.28	233.58%	487.30
26	10.01	9.75	5.58	55.78%	3.83	5.65	56.45%	3.81
27	11.41	10.87	5.74	50.32%	3.97	5.90	51.68%	3.95
28	26.59	26.47	20.52	77.18%	18.89	16.85	63.36%	13.97
29	17.41	16.64	7.46	42.86%	5.41	8.36	48.04%	6.45

TABLE A20
F-measure data on `printtokens`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	456.11	450.18	220.03	48.24%	219.36	161.49	35.41%	162.05
2	55.20	53.64	27.70	50.17%	28.26	21.27	38.53%	20.47
3	73.28	75.70	39.95	54.52%	38.78	32.93	44.93%	30.08
4	91.41	91.87	56.83	62.17%	55.69	50.93	55.72%	48.90
5	7.16	6.55	4.11	57.42%	3.20	4.47	62.39%	3.08
6	14.95	14.91	6.04	40.42%	5.18	6.10	40.79%	4.36
7	97.35	98.07	47.11	48.39%	46.36	41.35	42.48%	40.10

TABLE A21
F-measure data on `printtokens2`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	10.69	10.75	5.25	49.16%	4.42	5.45	50.97%	3.93
2	10.32	10.37	5.02	48.70%	4.18	5.28	51.23%	3.79
3	246.72	250.76	197.19	79.93%	195.32	290.36	117.69%	300.13
4	8.21	8.06	3.95	48.09%	2.99	4.26	51.84%	2.86
5	16.25	16.12	10.45	64.32%	9.98	10.19	62.74%	8.72
6	5.33	4.89	3.13	58.77%	2.19	3.46	64.99%	2.25
7	12.73	12.78	6.09	47.86%	5.06	6.21	48.75%	4.64
8	10.85	10.07	4.84	44.60%	3.82	5.11	47.12%	3.53
9	44.14	43.57	18.48	41.88%	18.27	15.29	34.64%	12.97
10	16.25	16.12	10.45	64.32%	9.98	10.19	62.74%	8.72

TABLE A22
F-measure data on `replace`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	146.86	150.89	103.12	70.22%	100.26	118.25	80.52%	117.21
2	208.22	215.89	186.20	89.43%	188.82	198.78	95.47%	207.34
3	87.33	90.86	85.93	98.40%	82.80	86.56	99.12%	86.90
4	43.60	44.15	39.31	90.16%	37.30	67.78	155.47%	66.97
5	57.17	56.23	67.06	117.30%	68.81	90.43	158.17%	95.90
6	51.76	53.02	90.13	174.12%	92.45	200.28	386.92%	213.42
7	63.93	64.47	62.29	97.43%	64.12	80.75	126.32%	84.48
8	104.42	101.85	69.60	66.65%	65.65	90.73	86.89%	93.30
9	248.82	246.24	510.04	204.98%	523.93	1019.27	409.64%	1036.60
10	233.26	225.35	417.57	179.01%	434.28	770.69	330.39%	774.09
11	248.82	246.24	510.04	204.98%	523.93	1019.27	409.64%	1036.60
12	18.13	17.37	14.07	77.63%	13.40	12.60	69.50%	11.37
13	41.02	40.46	38.05	92.76%	35.72	60.05	146.39%	62.18
14	36.05	36.07	54.84	152.11%	55.31	93.87	260.36%	102.70
15	91.21	88.20	69.79	76.51%	58.78	58.21	63.82%	54.36
16	63.93	64.47	62.29	97.43%	64.12	80.75	126.32%	84.48
17	467.79	475.68	611.58	130.74%	630.08	611.47	130.71%	630.15
18	27.81	27.78	45.41	163.28%	46.80	95.95	345.03%	109.27
19	2604.75	2623.05	907.56	34.84%	964.92	789.75	30.32%	808.45
20	518.01	521.94	660.65	127.54%	655.59	660.63	127.53%	655.60
21	2142.99	2111.79	842.66	39.32%	832.82	758.64	35.40%	780.90
22	137.80	132.78	210.80	152.97%	207.70	376.50	273.22%	385.52
23	418.51	417.10	473.04	113.03%	492.49	748.57	178.87%	756.10
24	51.73	50.61	33.34	64.44%	33.15	40.59	78.47%	40.04
25	2385.25	2321.38	1650.46	69.19%	1692.29	2383.61	99.93%	2378.74
26	50.95	50.57	71.80	140.91%	72.93	129.01	253.19%	141.93
27	42.21	40.78	27.20	64.44%	25.72	32.81	77.72%	32.64
28	40.34	40.25	20.70	51.31%	18.14	28.83	71.47%	27.20
29	82.82	81.89	48.71	58.81%	46.45	56.21	67.87%	55.98
30	19.91	19.65	12.41	62.32%	11.11	15.37	77.23%	14.32
31	27.34	27.36	45.84	167.66%	48.02	93.63	342.43%	106.26

TABLE A23
F-measure data on `schedule`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	396.32	395.60	56.22	14.19%	56.15	48.18	12.16%	44.96
2	12.96	12.57	47.21	364.26%	45.88	30.27	233.57%	33.62
3	16.00	15.54	57.00	356.36%	56.93	57.21	357.63%	63.52
4	9.65	9.14	48.60	503.38%	49.71	34.52	357.53%	40.07
5	77.75	78.83	51.28	65.95%	46.10	36.96	47.54%	32.51
6	396.32	395.60	56.22	14.19%	56.15	48.18	12.16%	44.96
7	101.78	102.47	161.14	158.32%	161.47	117.84	115.78%	117.16
8	104.75	109.12	523.72	499.96%	524.82	330.23	315.25%	345.64
9	121.24	123.53	24.23	19.98%	19.79	19.14	15.78%	15.02

TABLE A24
F-measure data on `schedule2`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	88.34	87.11	65.41	74.04%	64.23	34.69	39.27%	30.92
2	104.68	104.80	105.78	101.04%	99.38	95.81	91.52%	96.66
3	111.45	111.98	48.48	43.50%	42.99	33.09	29.69%	27.84
4	33.92	46.02	836.20	2465.22%	833.37	518.08	1527.36%	507.73
5	163.30	160.99	45.67	27.97%	44.34	34.87	21.35%	29.12
6	447.98	449.46	88.28	19.71%	83.39	105.99	23.66%	97.82
7	104.68	104.80	105.78	101.04%	99.38	95.81	91.52%	96.66
8	66.64	64.42	22.18	33.29%	19.08	16.74	25.11%	12.39
9	68.50	66.75	23.22	33.90%	19.85	17.12	24.99%	12.81

TABLE A25
F-measure data on `sort`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	97.46	94.12	96.58	99.10%	102.41	16.88	17.32%	13.39
2	22.60	22.20	9.79	43.33%	8.35	10.31	45.62%	8.84
3	81.83	78.85	96.32	117.71%	103.49	16.79	20.52%	13.23
4	168.96	165.34	75.46	44.66%	72.01	54.23	32.10%	50.21
5	10.17	9.20	12.84	126.22%	12.87	5.87	57.70%	4.34
6	26.37	25.64	29.98	113.72%	28.91	15.93	60.43%	14.02
7	37.70	37.35	14.96	39.69%	13.92	12.18	32.30%	10.66
8	37.89	37.38	14.87	39.25%	13.90	12.34	32.56%	10.78
9	241.25	243.33	80.23	33.26%	74.84	213.80	88.62%	210.13
10	334.95	336.92	187.04	55.84%	182.25	165.69	49.47%	155.96
11	111.14	106.75	105.65	95.06%	112.24	17.55	15.79%	14.12
12	89.35	87.68	71.16	79.64%	74.59	17.45	19.53%	14.11
13	333.80	331.32	185.86	55.68%	175.50	160.95	48.22%	148.52
14	334.08	346.59	218.64	65.44%	217.10	159.51	47.75%	149.17
15	506.63	500.51	436.00	86.06%	425.10	370.78	73.18%	346.82
16	244.03	252.56	114.22	46.80%	110.60	132.83	54.43%	124.16
17	241.42	235.40	69.80	28.91%	64.33	129.37	53.59%	124.64
18	240.46	249.31	105.96	44.06%	100.55	133.34	55.45%	123.25
19	326.57	332.04	121.44	37.19%	112.42	134.04	41.04%	124.01
20	244.52	251.90	80.99	33.12%	75.54	116.97	47.83%	111.03
21	256.44	257.36	210.46	82.07%	203.62	146.64	57.18%	141.64
22	243.53	247.01	103.97	42.69%	100.87	132.47	54.40%	124.76
23	160.44	162.71	66.34	41.35%	63.64	116.97	72.90%	112.75
24	343.90	357.48	239.16	69.54%	237.26	163.54	47.56%	153.34
25	337.09	341.08	114.12	33.86%	107.35	55.71	16.53%	50.78
26	36.15	35.99	14.96	41.40%	14.00	12.11	33.51%	10.58
27	10.80	10.25	12.10	112.07%	12.58	6.47	59.95%	5.04
28	329.97	327.03	81.87	24.81%	76.91	130.32	39.49%	125.85
29	136.26	137.70	132.42	97.18%	124.15	160.57	117.84%	151.76
30	241.74	241.56	244.28	101.05%	240.35	83.29	34.45%	74.62
31	249.34	260.05	96.44	38.68%	95.88	134.04	53.76%	124.63
32	248.46	249.51	211.00	84.92%	199.82	93.62	37.68%	84.40
33	163.92	170.49	63.59	38.80%	58.61	114.08	69.59%	111.74
34	138.65	139.79	56.67	40.87%	51.04	102.47	73.90%	99.48
35	164.54	169.61	76.51	46.50%	75.46	130.63	79.39%	126.69
36	246.50	241.94	162.66	65.99%	150.14	98.08	39.79%	87.15
37	249.23	244.80	186.58	74.86%	186.08	98.08	39.36%	87.10
38	247.45	254.25	116.82	47.21%	114.45	133.32	53.88%	124.17
39	242.51	233.71	203.43	83.88%	196.51	98.43	40.59%	88.52
40	58.78	58.97	31.48	53.55%	25.28	9.60	16.32%	7.01
41	51.64	52.02	31.09	60.20%	25.18	9.53	18.45%	7.01
42	140.61	141.81	152.92	108.76%	151.48	80.90	57.54%	73.83
43	144.77	141.68	220.07	152.01%	218.26	110.01	75.99%	105.74
44	12.79	12.37	7.62	59.58%	6.17	6.76	52.81%	5.32
45	245.06	245.41	207.33	84.60%	206.37	97.45	39.77%	87.17
46	247.95	247.58	107.50	43.35%	101.47	143.02	57.68%	140.97
47	340.13	353.07	271.26	79.75%	259.96	144.45	42.47%	133.73
48	250.36	251.62	156.78	62.62%	152.88	97.45	38.93%	87.11

TABLE A26
F-measure data on `spline`

M-ID	RT F-measure	RT sDev	ARTmif F-measure	ARTmif F-ratio	ARTmif sDev	ARTsum F-measure	ARTsum F-ratio	ARTsum sDev
1	17.36	16.76	7.01	40.40%	5.38	13.19	75.97%	13.09
2	27.63	27.40	8.31	30.09%	6.26	9.59	34.70%	7.82
3	13.17	13.00	6.87	52.16%	5.47	6.06	46.04%	4.68
4	78.61	79.37	15.97	20.32%	14.05	16.72	21.27%	14.56
5	28.53	27.84	9.04	31.68%	7.04	10.57	37.05%	9.73
6	10.94	10.90	5.22	47.76%	3.82	5.04	46.08%	3.70
7	26.53	25.69	13.08	49.30%	11.89	23.41	88.27%	23.76
8	44.07	42.29	71.19	161.52%	71.10	135.49	307.42%	131.06
9	47.49	45.20	31.51	66.34%	30.06	31.53	66.38%	30.06
10	43.50	42.56	19.91	45.77%	18.44	22.98	52.84%	21.85
11	12.92	12.44	5.96	46.14%	4.54	6.17	47.71%	4.98
12	77.60	76.57	24.22	31.21%	21.93	21.99	28.33%	19.27
13	45.37	45.15	30.92	68.16%	28.40	77.87	171.63%	92.80
14	86.13	87.35	47.13	54.73%	45.80	37.77	43.86%	36.82
15	32.97	33.73	19.22	58.30%	17.57	15.19	46.07%	13.46
16	15.26	14.54	29.52	193.51%	30.71	27.50	180.24%	25.74

TABLE A27
F-measure data on `tcas`

M-ID	RT F-measure	RT sDev	ARTmif F-measure	ARTmif F-ratio	ARTmif sDev	ARTsum F-measure	ARTsum F-ratio	ARTsum sDev
1	21.77	21.60	43.48	199.70%	42.69	45.57	209.31%	54.51
2	34.07	33.89	67.62	198.44%	65.06	62.65	183.87%	58.72
3	54.55	55.40	62.91	115.33%	56.39	66.60	122.10%	57.05
4	46.03	45.71	56.89	123.59%	53.05	71.91	156.22%	55.89
5	92.85	90.62	53.47	57.59%	48.35	44.81	48.26%	41.71
6	216.22	216.29	415.54	192.18%	398.35	395.97	183.13%	563.45
7	55.08	58.10	91.02	165.26%	92.91	115.59	209.87%	89.46
8	730.75	745.14	928.62	127.08%	893.77	844.43	115.56%	582.84
9	272.46	261.88	431.67	158.43%	442.12	405.95	149.00%	287.28
10	216.22	216.29	401.88	185.87%	384.49	400.08	185.03%	524.35
11	210.46	211.03	406.38	193.09%	391.19	446.85	212.32%	482.28
12	19.20	18.21	15.82	82.42%	14.54	14.85	77.34%	13.40
13	240.58	241.49	121.84	50.64%	119.35	82.42	34.26%	77.85
14	40.93	40.65	78.77	192.45%	78.00	87.61	214.05%	88.88
15	92.85	90.62	53.47	57.59%	48.35	44.81	48.26%	41.71
16	41.17	41.96	82.02	199.20%	83.77	64.31	156.19%	78.52
17	74.34	77.70	146.16	196.61%	146.40	170.29	229.07%	182.19
18	95.67	92.10	155.89	162.96%	150.03	192.89	201.63%	180.64
19	144.43	143.32	311.78	215.87%	317.91	226.89	157.09%	306.89
20	158.97	158.54	231.35	145.53%	220.31	226.73	142.63%	176.88
21	131.05	127.01	123.91	94.55%	115.70	149.10	113.77%	118.65
22	149.06	144.90	176.01	118.08%	164.11	217.89	146.18%	181.20
23	61.79	62.54	77.84	125.98%	75.40	67.85	109.81%	58.41
24	148.11	144.33	191.06	129.00%	188.96	232.44	156.93%	178.78
25	344.63	343.06	606.44	175.97%	606.43	623.85	181.02%	459.39
26	132.24	133.98	67.03	50.69%	61.19	46.16	34.91%	39.93
27	92.85	90.62	53.47	57.59%	48.35	44.81	48.26%	41.71
28	26.98	27.09	32.18	119.29%	29.60	31.30	116.03%	27.24
29	74.10	73.85	90.65	122.33%	86.79	106.62	143.88%	88.72
30	41.59	42.02	49.08	118.00%	45.48	49.50	119.02%	42.74
31	216.22	216.29	401.88	185.87%	384.49	380.11	175.80%	532.96
32	1049.66	1013.08	1717.96	163.67%	1747.59	1202.44	114.56%	984.95
33	18.26	18.08	35.36	193.69%	34.53	40.22	220.26%	42.17
34	18.67	17.78	13.36	71.54%	11.58	11.81	63.28%	10.35
35	26.98	27.09	32.18	119.29%	29.60	31.30	116.03%	27.24
36	17.94	17.37	26.03	145.10%	24.29	31.18	173.84%	28.80
37	15.56	15.13	26.01	167.10%	24.56	26.59	170.84%	27.19
38	25.92	25.38	43.70	168.60%	40.74	47.61	183.69%	43.97
39	344.63	343.06	606.44	175.97%	606.43	623.85	181.02%	462.46
40	17.94	17.37	26.03	145.10%	24.29	31.18	173.84%	28.80
41	46.03	45.71	57.64	125.23%	54.45	56.42	122.57%	43.80

TABLE A28
F-measure data on `totinfo`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	5.19	4.75	3.03	58.26%	1.77	3.32	64.01%	1.87
2	119.13	115.90	44.50	37.36%	43.74	140.79	118.18%	159.43
3	276.96	286.66	666.26	240.56%	640.63	835.75	301.76%	619.45
4	23.51	22.46	18.55	78.88%	17.93	18.82	80.04%	17.68
5	7.82	7.54	18.79	240.31%	16.59	25.15	321.64%	28.33
6	16.09	15.45	14.88	92.52%	14.36	16.84	104.69%	17.47
7	6.62	6.11	5.41	81.80%	4.28	5.82	87.91%	4.92
8	4.07	3.55	3.34	81.93%	2.41	3.34	81.98%	2.39
9	7.24	7.00	16.22	224.09%	14.23	26.40	364.70%	28.88
10	105.46	104.56	48.89	46.36%	43.49	56.95	54.00%	52.91
11	4.07	3.55	3.34	81.93%	2.41	3.34	81.98%	2.39
12	23.39	22.91	21.85	93.41%	21.91	22.28	95.25%	23.30
13	6.35	5.89	5.21	82.03%	4.00	5.49	86.41%	4.61
14	373.69	390.93	961.06	257.18%	968.38	795.14	212.78%	657.78
15	4.07	3.55	3.34	81.93%	2.41	3.34	81.98%	2.39
16	4.81	4.22	3.94	81.92%	3.02	4.00	83.06%	3.09
17	17.29	16.44	15.32	88.66%	14.42	17.15	99.19%	16.60
18	6.97	6.62	3.80	54.47%	2.66	4.02	57.64%	2.50
19	8.62	8.30	8.70	100.91%	8.14	8.59	99.70%	8.25
20	9.83	9.61	5.16	52.45%	3.41	5.39	54.79%	3.60
21	6.72	6.33	3.14	46.69%	2.01	3.38	50.26%	1.68
22	33.65	34.01	32.27	95.90%	27.49	29.27	86.97%	24.51
23	11.01	10.23	8.34	75.80%	7.06	9.15	83.12%	8.50

TABLE A29
F-measure data on `uniq`

M-ID	RT		ARTmif			ARTsum		
	F-measure	sDev	F-measure	F-ratio	sDev	F-measure	F-ratio	sDev
1	11.46	10.98	6.52	56.93%	5.13	6.82	59.53%	5.53
2	15.87	15.70	10.96	69.06%	9.72	8.31	52.37%	6.49
3	13.03	12.87	13.69	105.06%	13.03	13.75	105.54%	13.19
4	16.42	15.48	12.90	78.55%	11.33	13.27	80.82%	12.24
5	32.93	32.70	29.91	90.83%	27.16	35.66	108.27%	32.80
6	40.24	40.79	27.70	68.85%	25.34	35.67	88.64%	37.20
7	13.64	13.18	12.88	94.42%	11.84	17.75	130.14%	18.17
8	26.34	25.38	22.96	87.16%	21.45	23.18	88.00%	23.56
9	25.02	23.83	20.22	80.80%	18.70	20.45	81.72%	21.31
10	35.34	36.14	28.66	81.11%	26.27	38.46	108.84%	35.79
11	16.91	16.20	13.24	78.29%	11.73	13.61	80.50%	12.33
12	11.47	10.95	10.65	92.84%	9.64	10.83	94.43%	9.90
13	38.47	39.86	35.20	91.49%	33.90	38.46	99.98%	35.37
14	43.10	44.56	26.81	62.21%	25.59	17.74	41.16%	14.74
15	71.86	71.97	12.68	17.65%	10.65	9.84	13.69%	7.23
16	11.81	11.10	10.75	91.06%	9.26	12.95	109.64%	12.53
17	39.45	40.38	24.70	62.61%	24.34	16.22	41.12%	14.03
18	17.27	17.27	10.78	62.40%	10.05	7.92	45.83%	6.53
19	13.02	12.42	7.40	56.83%	5.47	8.33	63.98%	6.94
20	419.13	419.45	134.04	31.98%	133.97	60.19	14.36%	55.20
21	30.01	29.38	20.39	67.93%	18.75	21.87	72.88%	21.89
22	21.79	21.41	13.50	61.96%	11.27	13.87	63.67%	12.31
23	23.68	22.83	17.43	73.61%	15.97	11.55	48.79%	9.86
24	60.49	59.48	41.08	67.92%	40.95	30.24	50.00%	30.32
25	22.29	21.33	16.23	72.82%	14.96	10.81	48.48%	8.96
26	10.70	10.45	5.27	49.22%	4.37	5.21	48.67%	4.13
27	11.99	11.31	6.61	55.10%	4.87	7.37	61.49%	6.00
28	25.79	25.60	18.81	72.94%	17.13	13.36	51.80%	12.13
29	23.65	22.76	16.30	68.93%	15.00	11.29	47.75%	9.40

TABLE A30
Number of Faults for Which the the Technique on the Top Row has a Higher (Better) PMA Than the Technique on the Left

(a) cal

	RT	ARTmif	ARTsum
RT	N/A	**11**	**11**
ARTmif	0	N/A	8
ARTsum	0	3	N/A

(b) comm

	RT	ARTmif	ARTsum
RT	N/A	**27**	**27**
ARTmif	0	N/A	13
ARTsum	0	14	N/A

(c) grep

	RT	ARTmif	ARTsum
RT	N/A	**17**	**20**
ARTmif	3	N/A	11
ARTsum	0	9	N/A

(d) look

	RT	ARTmif	ARTsum
RT	N/A	**22**	**21**
ARTmif	7	N/A	13
ARTsum	8	16	N/A

(e) printtokens

	RT	ARTmif	ARTsum
RT	N/A	**7**	**7**
ARTmif	0	N/A	5
ARTsum	0	2	N/A

(f) printtokens2

	RT	ARTmif	ARTsum
RT	N/A	**10**	**9**
ARTmif	0	N/A	3
ARTsum	1	7	N/A

(g) replace

	RT	ARTmif	ARTsum
RT	N/A	18	14
ARTmif	13	N/A	**5**
ARTsum	17	**26**	N/A

(h) schedule

	RT	ARTmif	ARTsum
RT	N/A	4	4
ARTmif	5	N/A	8
ARTsum	5	1	N/A

(i) schedule2

	RT	ARTmif	ARTsum
RT	N/A	6	**8**
ARTmif	3	N/A	8
ARTsum	1	1	N/A

(j) sort

	RT	ARTmif	ARTsum
RT	N/A	**41**	**47**
ARTmif	7	N/A	31
ARTsum	1	17	N/A

(k) spline

	RT	ARTmif	ARTsum
RT	N/A	**14**	**13**
ARTmif	2	N/A	6
ARTsum	3	10	N/A

(l) tcas

	RT	ARTmif	ARTsum
RT	N/A	**8**	**7**
ARTmif	33	N/A	21
ARTsum	34	20	N/A

(m) totinfo

	RT	ARTmif	ARTsum
RT	N/A	**18**	17
ARTmif	5	N/A	3
ARTsum	6	**20**	N/A

(n) uniq

	RT	ARTmif	ARTsum
RT	N/A	**28**	**24**
ARTmif	1	N/A	12
ARTsum	5	17	N/A