SSDEEPER: EVALUATING AND IMPROVING SSDEEP

By
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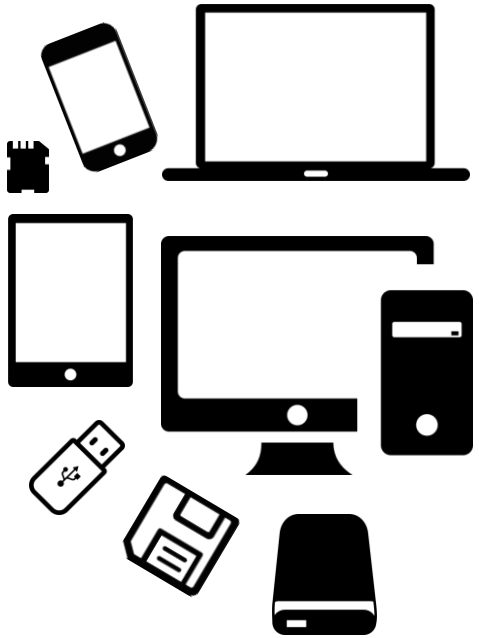
Introduction

The problem of scale



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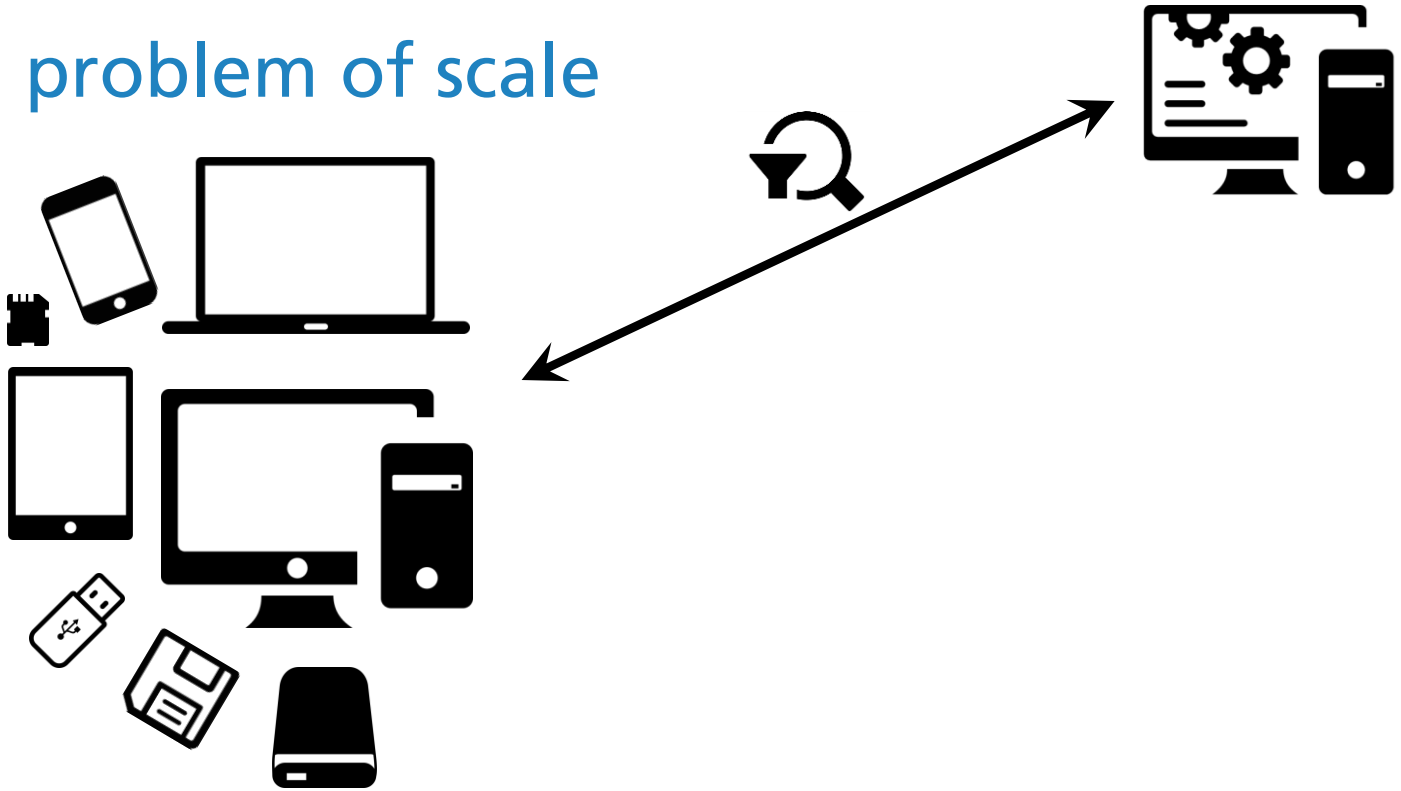
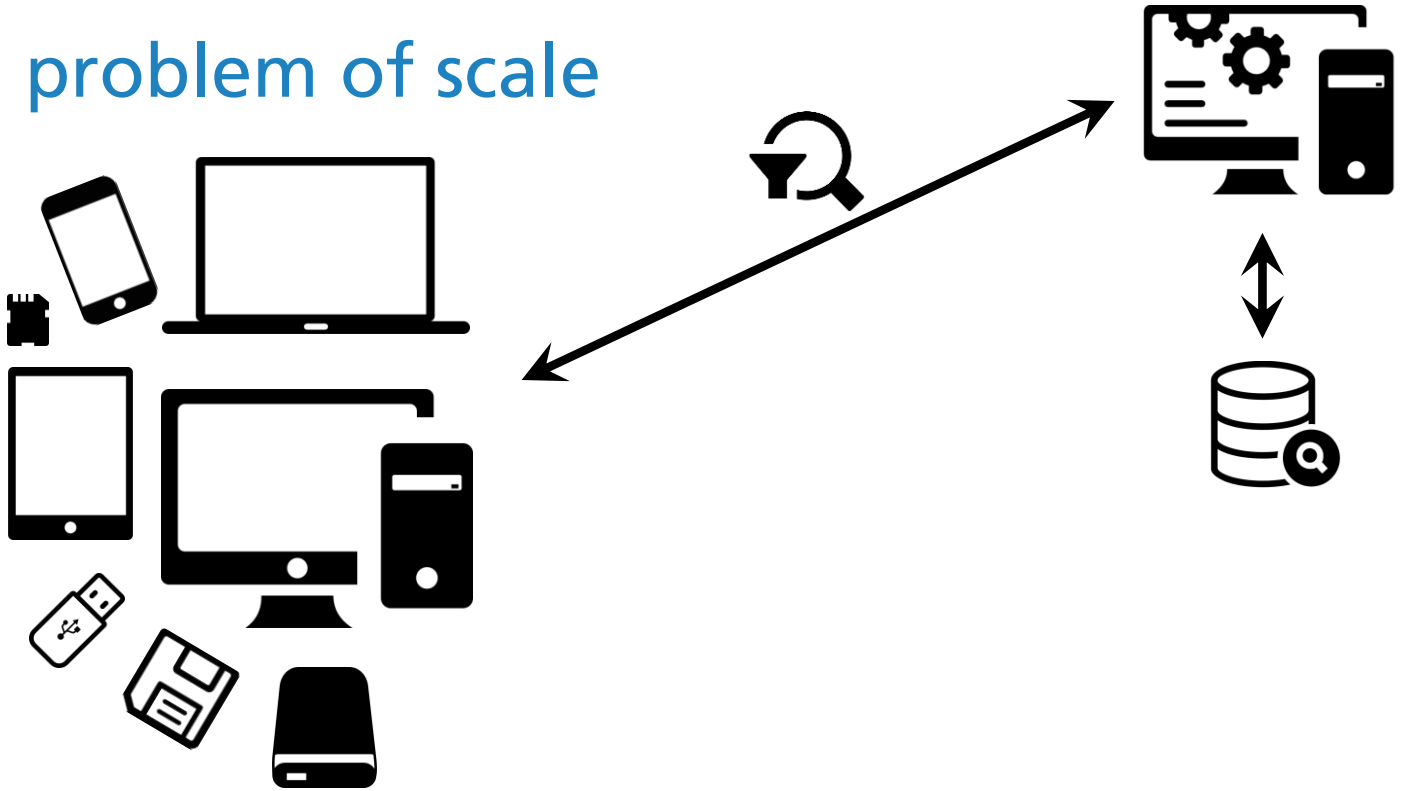


Automated systems

Introduction

The problem of scale

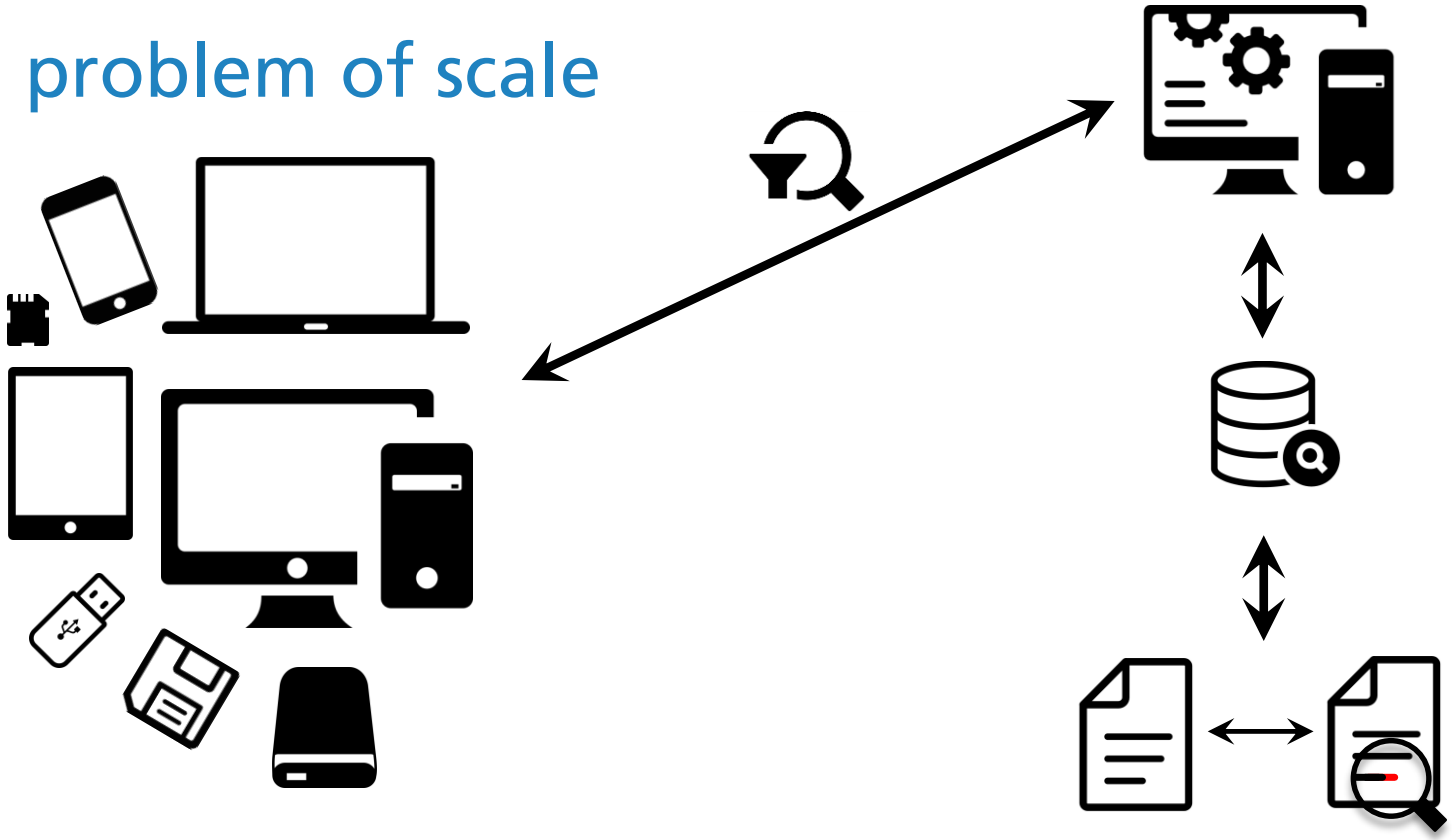


Automated systems

Traditional technique

Introduction

The problem of scale



Automated systems

Traditional technique

Limitation

Introduction – Similarity

- What is similarity?
  - Lower level approximates the similarity between two byte sequences
    - File type agnostic and fast
  - Higher level attempts to interpret the actual content
    - File type specific, requires parsing and interpretation of bytes

Introduction – Similarity Hashing

- What is similarity?
  - Lower level approximates the similarity between two byte sequences
    - File type agnostic and fast
  - Higher level attempts to interpret the actual content
    - File type specific, requires parsing and interpretation of bytes
- Similarity Hashing
  - On the lower level of abstraction
  - Similarity Preserving Hash Function (SPHF)
  - Comparison Function (CF)

Similarity Hashing – Properties

efficiency & usability

security

Similarity Hashing – Properties

efficiency & usability

Runtime

security

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Similarity Hashing – Properties

efficiency & usability

Runtime

Compression

security

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Similarity Hashing – Properties

efficiency & usability	Runtime
	Compression
	Accuracy
security	

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Similarity Hashing – Properties

efficiency & usability	Runtime
	Compression
	Accuracy
security	Coverage

Fraunhofer FKIE

Similarity Hashing – Properties

efficiency & usability	Runtime
	Compression
	Accuracy
security	Coverage
	Obfuscation resistance

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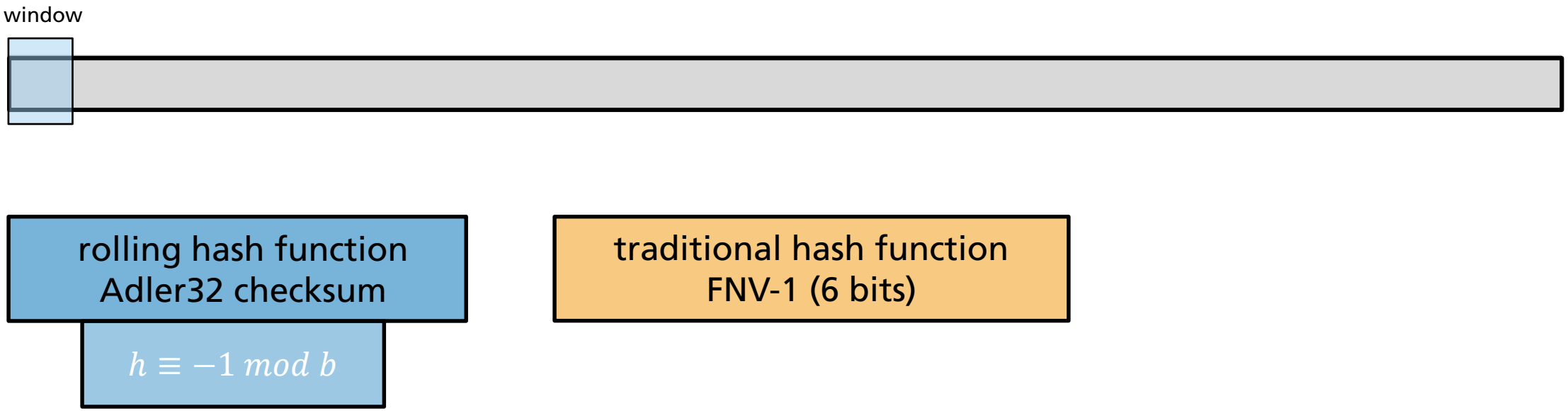
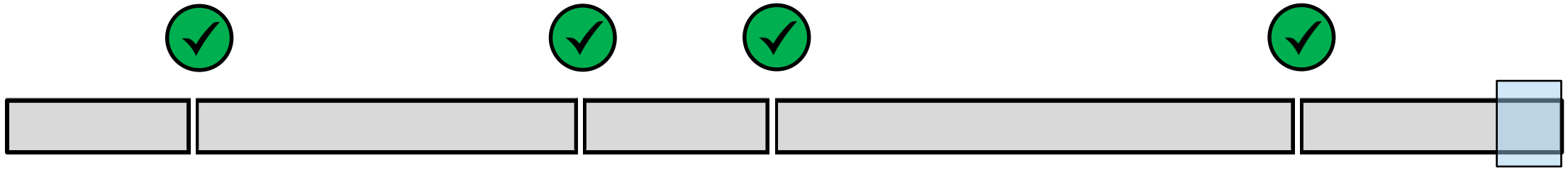
Similarity Hashing – ssdeep – SPHF



Similarity Hashing – ssdeep – SPHF



rolling hash function
Adler32 checksum

$h \equiv -1 \; mod \; b$

traditional hash function
FNV-1 (6 bits)

b	t	Q	y	N	F

- Recalculation if $len < 32$
  - Use $b = b/2$
  - `blocksize:hash:hash,filename`
- Variety of improvements

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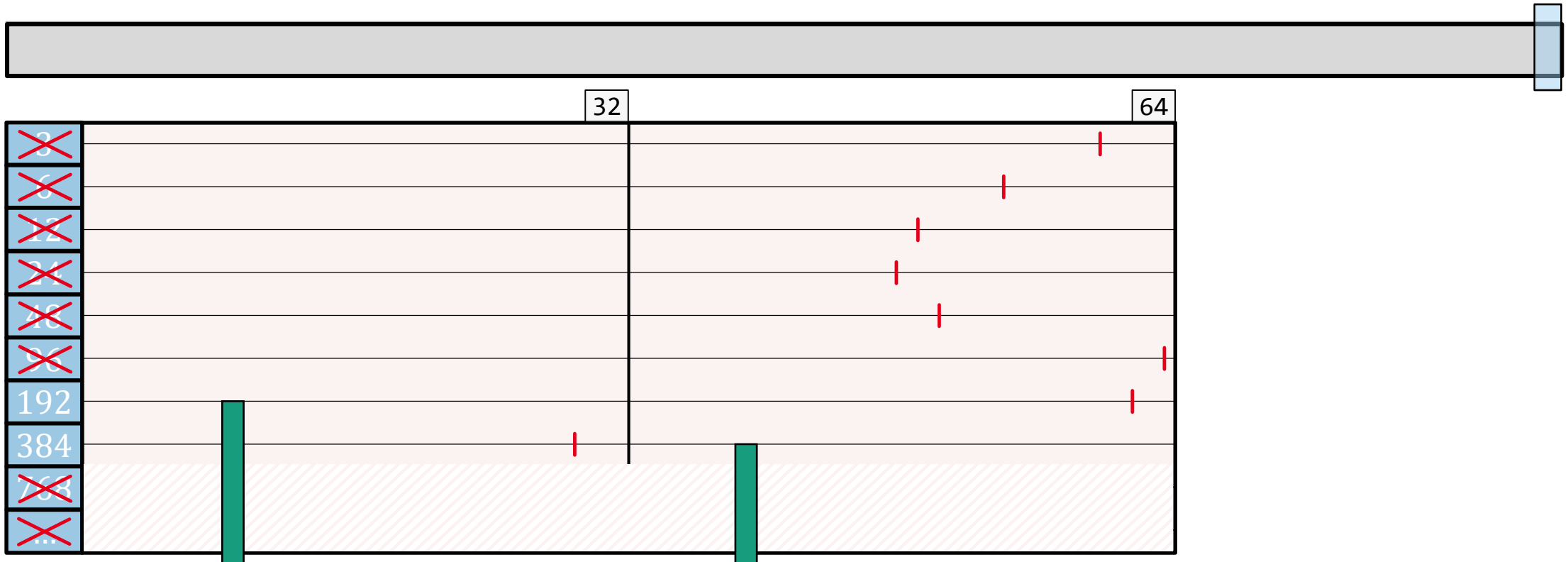
Similarity Hashing – ssdeep – SPHF




```
$ ssdeep somefile.jpg
ssdeep,1.1–blocksize:hash:hash,filename
192:tQyNFgeWKVwVyF18TYjEiHRElsOMuKyN46LouR1dPbCNXf4pMt9lj3IOYEVF:clxA1+0OAy1LVXPbAXf7t9ZbYOF,“somefile.jpg“
```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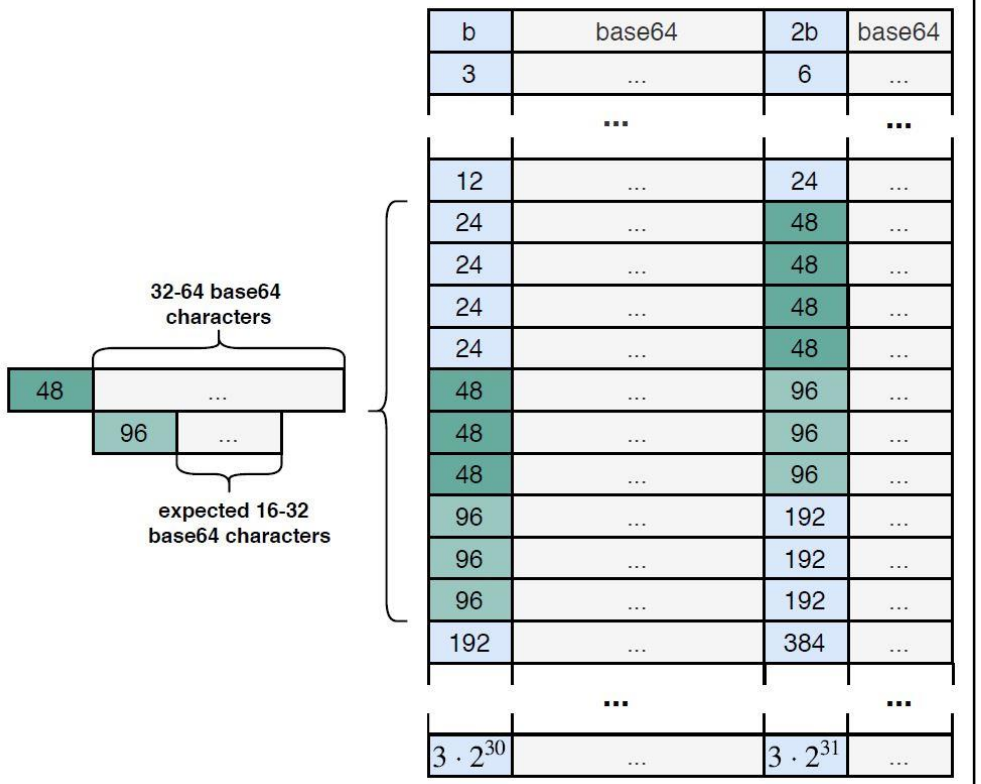
Similarity Hashing – ssdeep

- CF
  - Matching block sizes
  - Levensthein edit distance – string comparison



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Similarity Hashing – ssdeep

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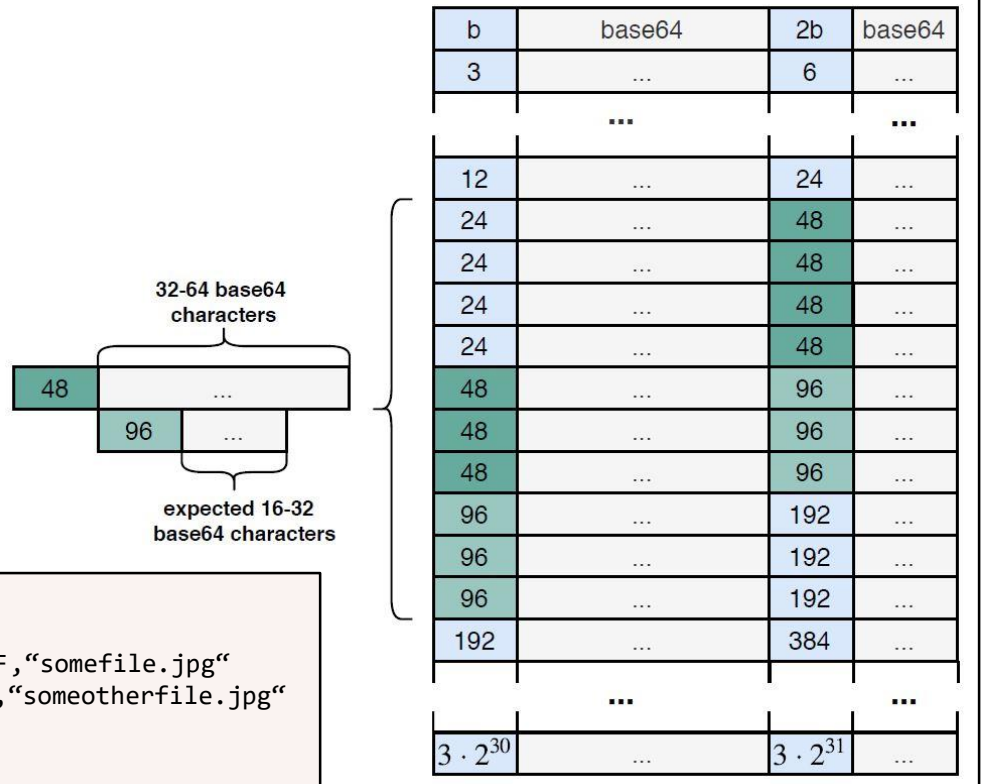


```
$ ssdeep somefile.jpg someotherfile.jpg
ssdeep,1.1–blocksize:hash:hash,filename
192:tQyNFgeWKVwVyF18TYjEiHRElsOMuKyN46LouR1dPbCNXf4pMt9lj3IOYEVF:clxA1+0OAy1LVXPbAXf7t9ZbYOF,“somefile.jpg“
192:tQyNFgeWKVuyF18TYjEiHRElsOMuKyN46LouR1dPbCNXf4pMt9lj3IOYEVF:clxA1+0OAy1LVXPbAXf7t9ZbYOF,“someotherfile.jpg“

$ ssdeep somefile.jpg someotherfile.jpg > known_hashes.txt
$ ssdeep –m known_hashes.txt someotherfile.jpg
someotherfile.jpg matches somefile.jpg (99)
someotherfile.jpg matches someotherfile.jpg (100)
```


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Similarity Hashing – ssdeep – Properties

efficiency & usability

Runtime

Compression

Accuracy

security

Coverage

Obfuscation resistance

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Similarity Hashing – ssdeep – Properties

efficiency & usability

Runtime

SPHF and CF components fast in calculation

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Obfuscation resistance

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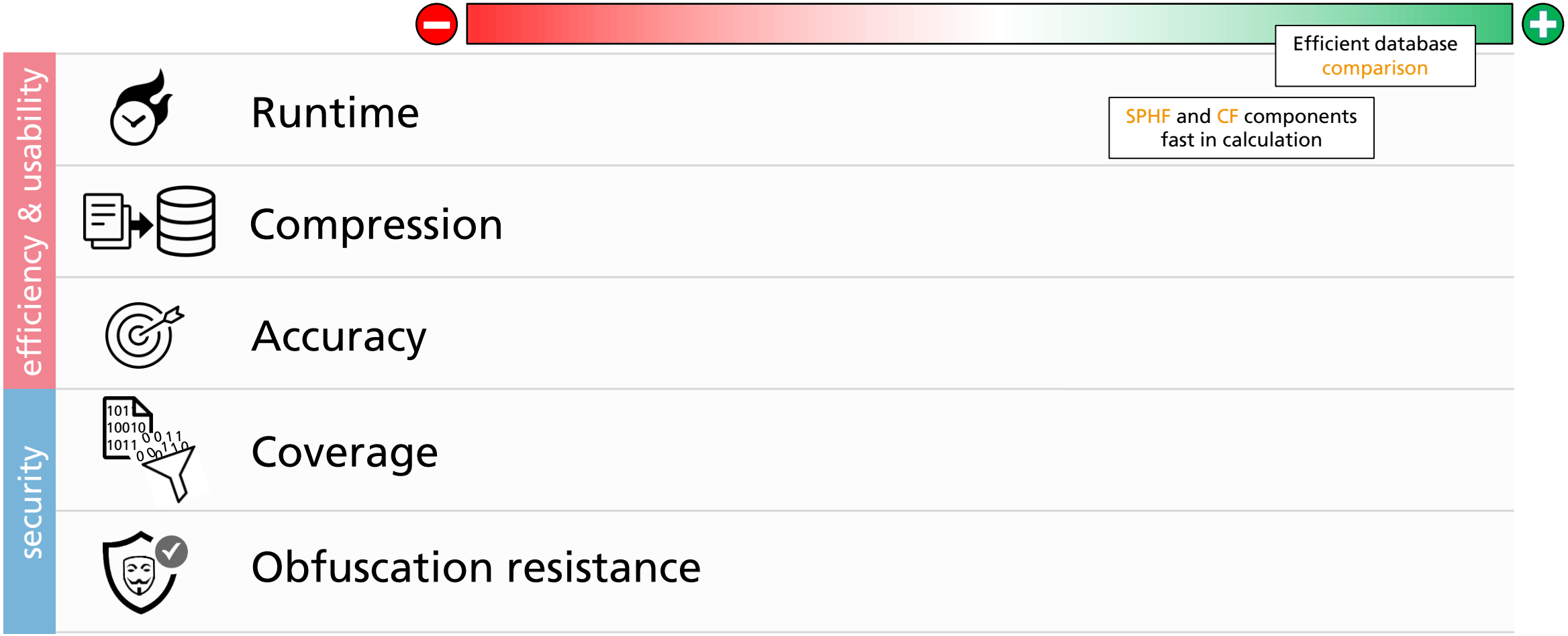

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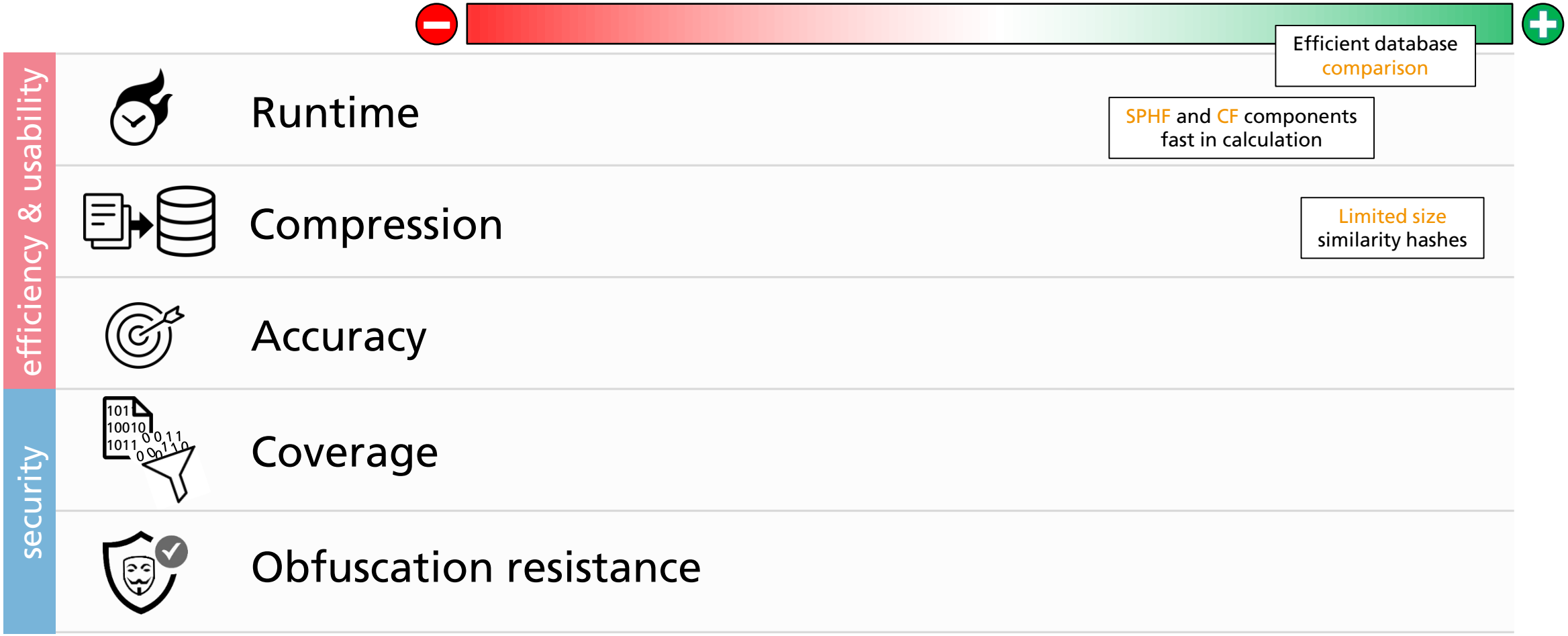

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Similarity Hashing – ssdeep – Properties

efficiency & usability

security

Runtime

Compression

Accuracy

Coverage

Obfuscation resistance

Efficient database comparison

SPHF and CF components fast in calculation

Limited size similarity hashes

Hash contains little information

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Similarity Hashing – ssdeep – Properties

efficiency & usability

security

Runtime	SPHF and CF components fast in calculation; Efficient database comparison
Compression	Limited size similarity hashes
Accuracy	Hash contains little information; False positives
Coverage	
Obfuscation resistance	

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Similarity Hashing – ssdeep – Properties

efficiency & usability

Runtime

Efficient database comparison

SPHF and CF components fast in calculation

Compression

Limited size similarity hashes

Accuracy

Hash contains little information

Limited comparability

False positives

security

Coverage

Obfuscation resistance

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Similarity Hashing – ssdeep – Properties

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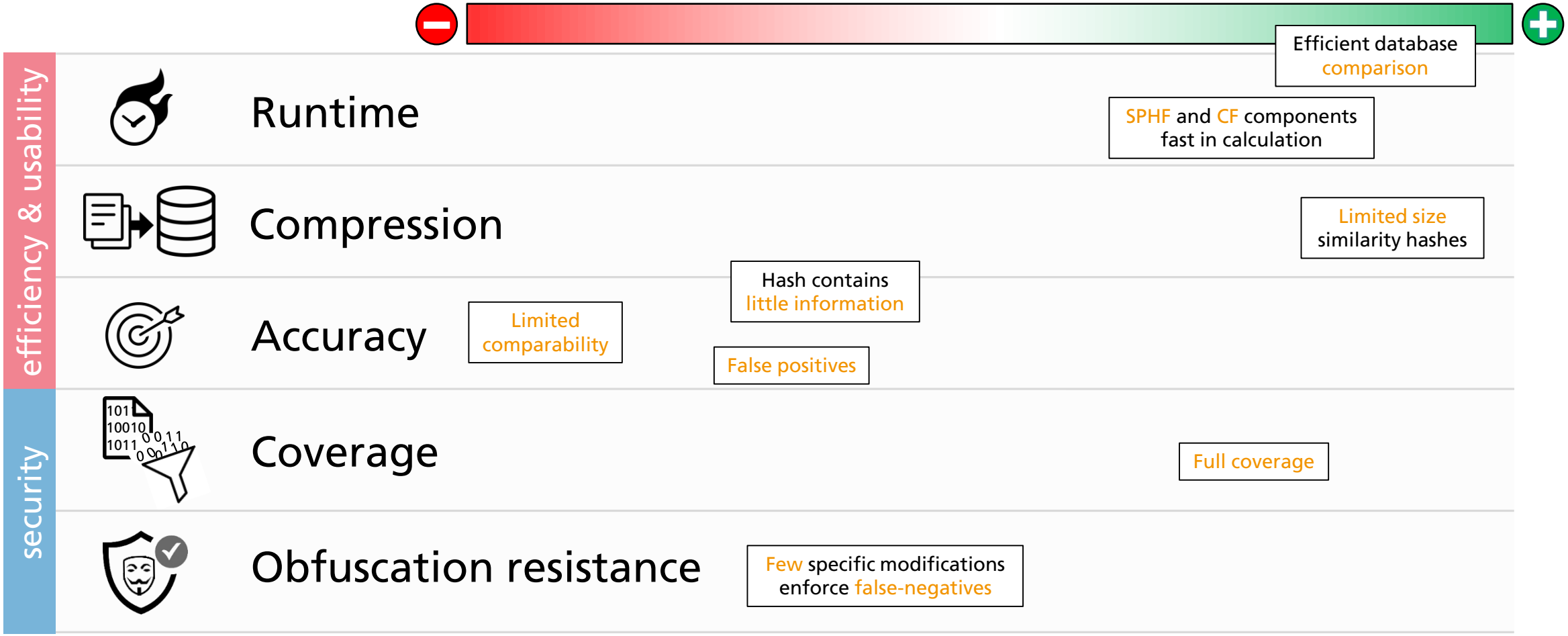
Similarity Hashing – ssdeep – Properties



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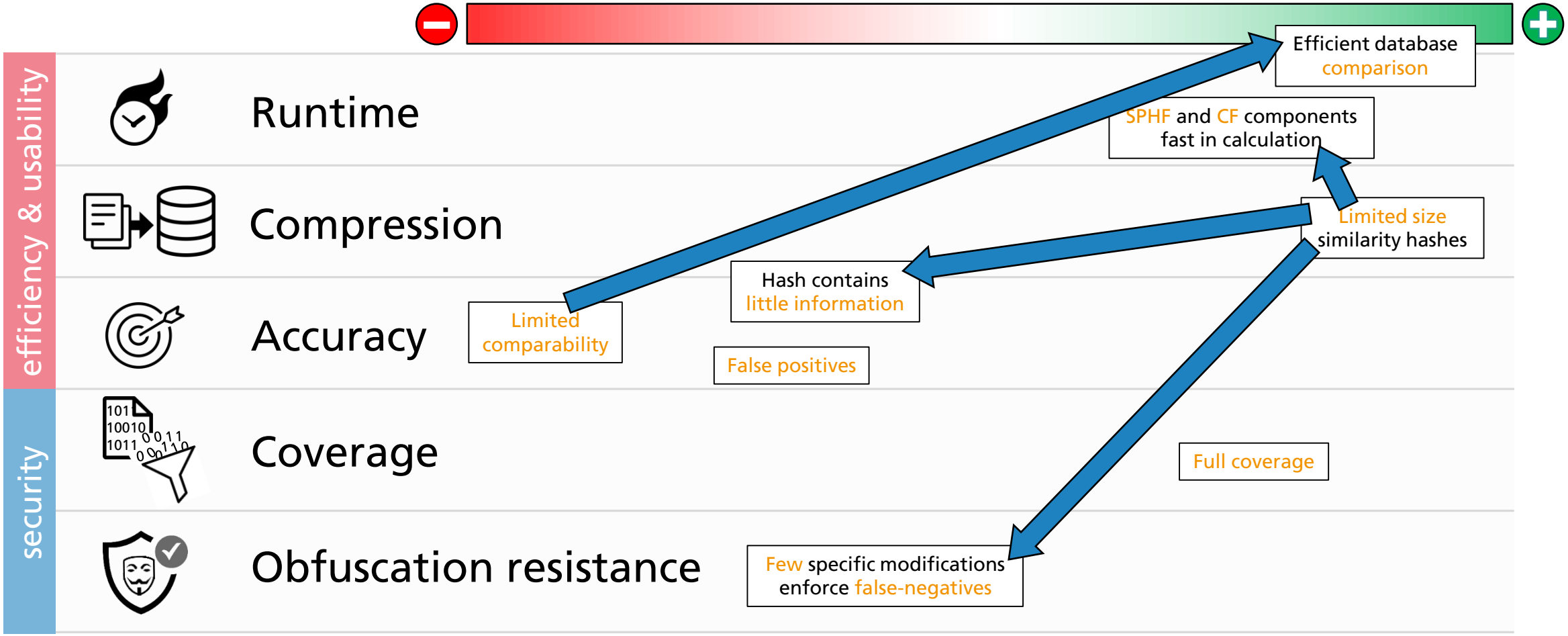
Similarity Hashing – ssdeep – Properties



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Analysis and improvement of ssdeep

Category	Inconsistencies	Code bugs	Possible approaches for an optimization
Modification	Modifications		
Goal	Assessment	Errors & Optimizations	Use Case

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Analysis – Inconsistencies

	SPHF	CF				
Restructuring of the SPHF						
Compatibility: 32 character-limitation						
Modification `-no32lim`	+	-	-	+	+	+
CF						
Maximum matching score						
Modification `-nomax`	○	+	○	+	○	-
Distance calculation via position array						
Modification `–nopa`	○	–	○	○	○	○
Common substring						
Modification `-nocommonsub`	○	○	○	+	○	+

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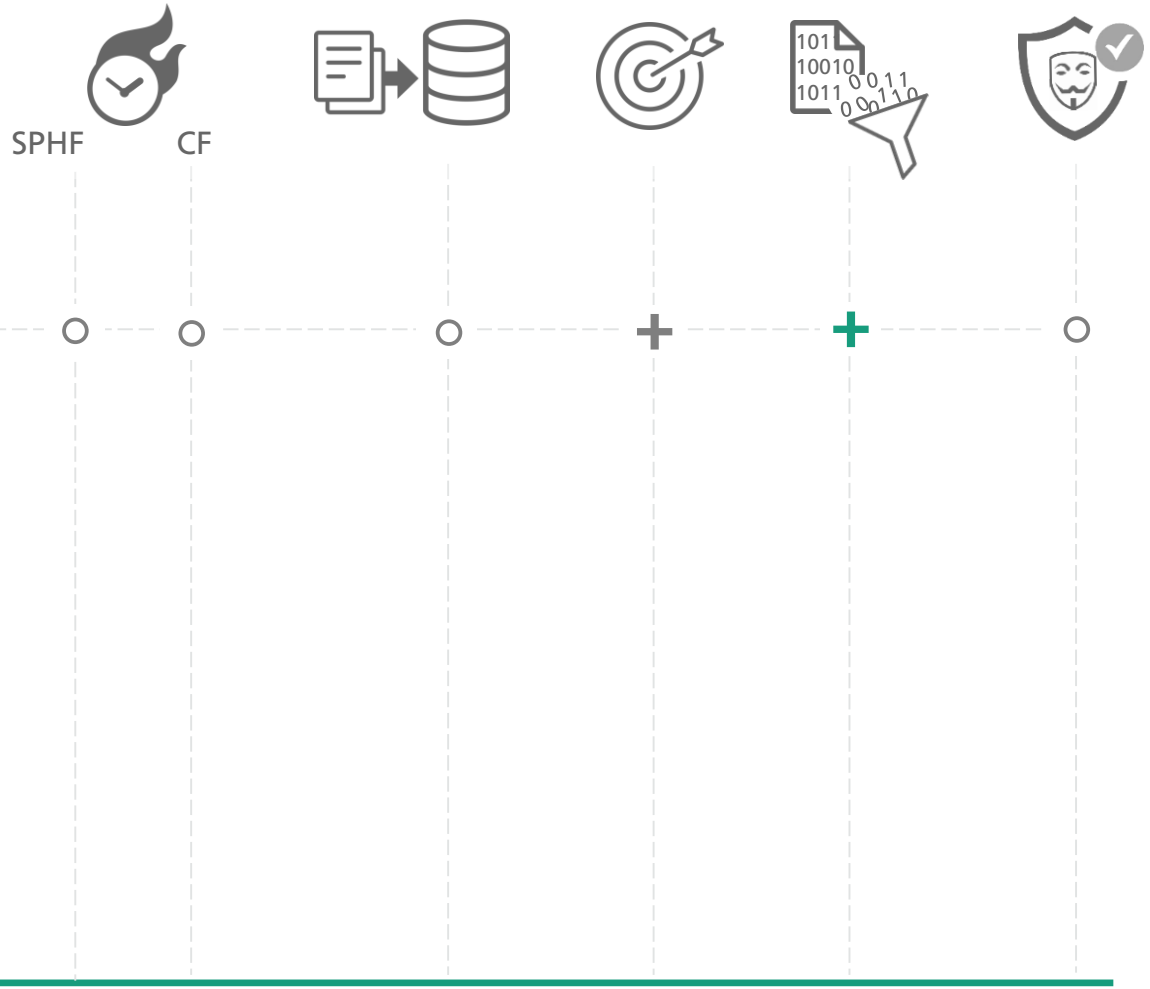
Analysis – Errors

- Last segment bug
  - Empty or missing segment
    - Modification `-bugfix`



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Analysis – Optimizations

	SPHF	CF				
Increased trigger progression constant						
Modification `-4b`	+	-	-	+	○	+
Exchanging the rolling hash function						
Modification `-djb2`	+	○	○	○	○	○
Modification `-polynomial`	+	○	○	○	○	○

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Analysis – Summarized

	SPHF	CF				
Modification -nocommonsub	○	○	○	+	○	+
Modification -nomax	○	+	○	+	○	-
Modification -nopa	○	-	○	○	○	○
Modification -no32lim, -bugfix (-refactored)	+	-	-	+	+	+
Modification -4b	+	-	-	+	○	+
Modification -djb2	+	○	○	○	○	○
Modification -polynomial	+	○	○	○	○	○

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Evaluation

- Similarity Hashing properties
- Most promising candidates
  - SPHF
    - `-refactored-djb2`
    - `-refactored-4b-djb2`
  - SPHF & CF
    - `-refactored-djb2-nomax`
    - `-refactored-4b-djb2-nocommonsub`
- Publicly available on our GitHub repository:
  `https://github.com/fkie-cad/ssdeeper`

Evaluation – Runtime – SPHF

	Properties of the hash database					Average throughput (KB/ms)	
SPHF	Compression ratio	Avg(len(s1))	Avg(len(s2))	Signature ratio	Backward-compatibility	Real data	Synthetic data
-original						48.629	69.619
-refactored-djb2						**57.608**	**89.068**
-refactored-4b-djb2						**58.876**	**89.751**

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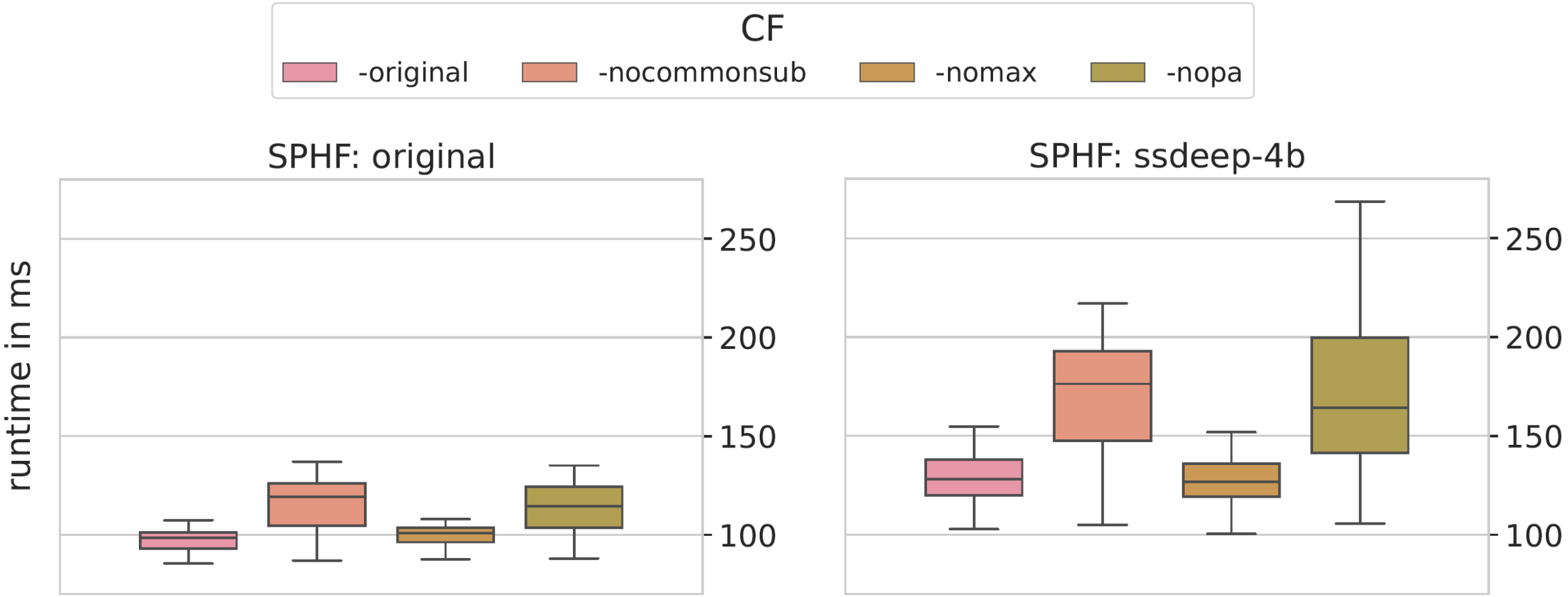
Evaluation – Runtime – CF



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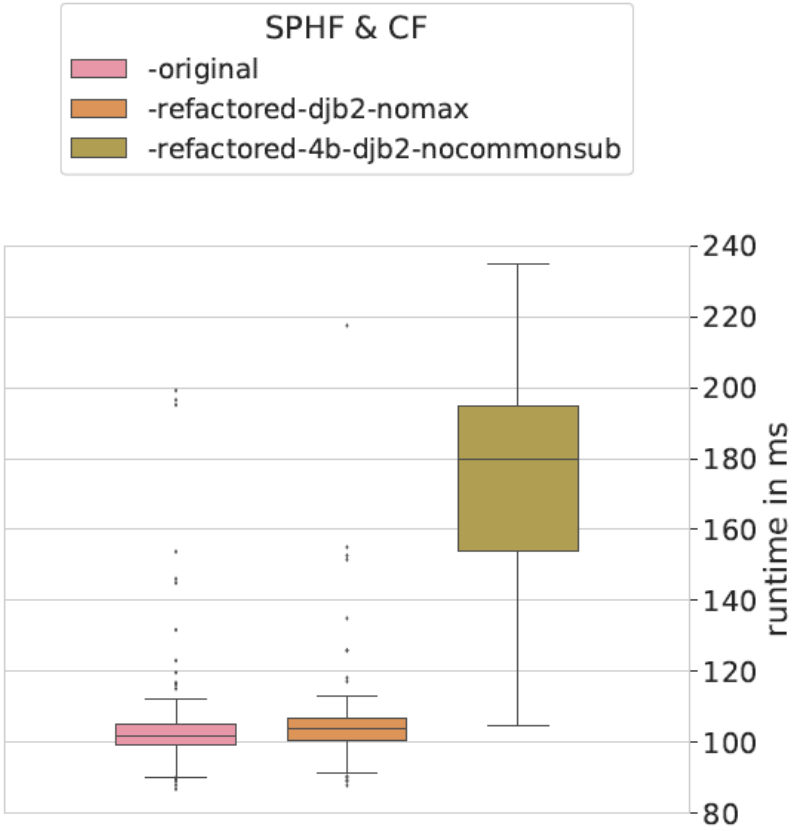
Evaluation – Runtime – SPHF & CF

SPHF & CF	Average runtime
-original	105.158
-refactored-djb2-nomax	**104.826**
-refactored-4b-djb2-nocommonsub	**175.919**



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Evaluation – Compression

	Properties of the hash database					Average throughput (KB/ms)	
SPHF	Compression ratio	Avg(len(s1))	Avg(len(s2))	Signature ratio	Backward-compatibility	Real data	Synthetic data
-original	4548.82	50.51	22.65	3.01	n/a	48.629	69.619
-refactored-djb2	**4446.78**	50.56	25.49	2.33	no	57.608	89.068
-refactored-4b-djb2	**3824.28**	77.68	19.79	5.23	no	58.876	89.751

Fraunhofer FKIE

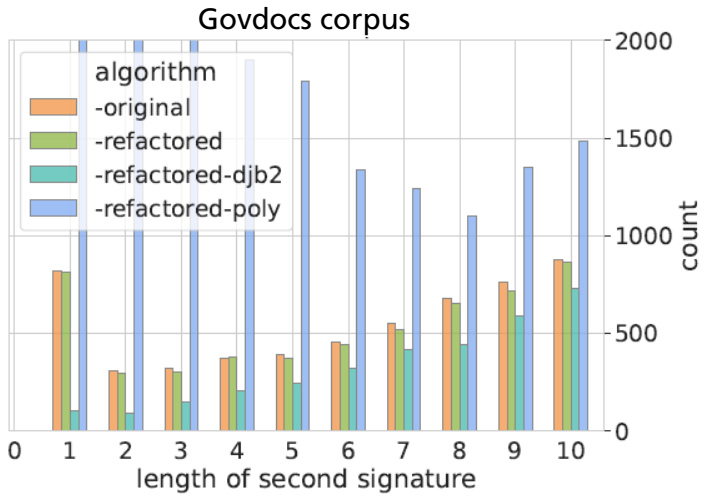
Evaluation – Compression

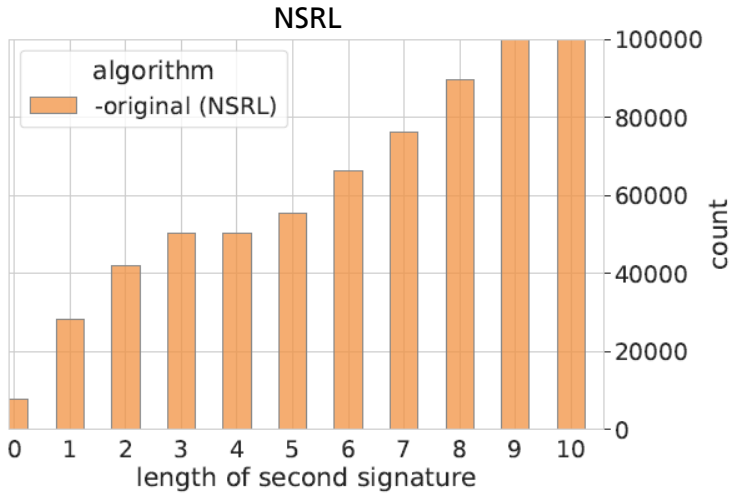
	Properties of the hash database					Average throughput (KB/ms)	
SPHF	Compression ratio	Avg(len(s1))	Avg(len(s2))	Signature ratio	Backward-compatibility	Real data	Synthetic data
`-original`	4548.82	50.51	22.65	3.01	n/a	48.629	69.619
`-refactored-djb2`	4446.78	**50.56**	**25.49**	**2.33**	no	57.608	89.068
`-refactored-4b-djb2`	3824.28	**77.68**	**19.79**	**5.23**	no	58.876	89.751

Fraunhofer FKIE

Evaluation – Compression

SPHF	Properties of the hash database				
	Compression ratio	Avg(len(s1))	Avg(len(s2))	Signature ratio	Backward-compatibility
`-original`	4548.82	50.51	22.65	3.01	n/a
`-refactored-djb2`	4446.78	**50.56**	**25.49**	**2.33**	no
`-refactored-4b-djb2`	3824.28	**77.68**	**19.79**	**5.23**	no





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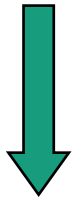
Evaluation – Accuracy

synthetic data corpus

- Randomness provided by input
  - Choice of rolling hash function
- Assessment of modification -4b

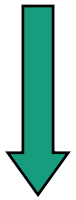
Evaluation – Accuracy

synthetic data corpus



- Randomness provided by input
  - Choice of rolling hash function
- Assessment of modification `-4b`

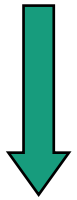
real data fragment corpus



- Worst case scenario
- Assessment of modification `-4b`, `-nocommonsub`, `-djb2` & `-nomax`

Evaluation – Accuracy

synthetic data corpus



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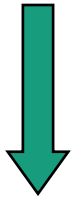
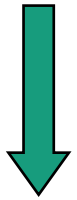


- Worst case scenario
- Assessment of modification `-4b`, `-nocommonsub`, `-djb2` & `-nomax`

- How to define accuracy and similarity?
  - The smallest error?
  - Here, variance & reliability

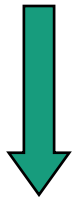
Evaluation – Accuracy

synthetic data corpus



- Randomness provided by input
  - Choice of rolling hash function
- Assessment of modification `-4b`

real data fragment corpus



- Worst case scenario
- Assessment of modification `-4b`, `-nocommonsub`, `-djb2` & `-nomax`

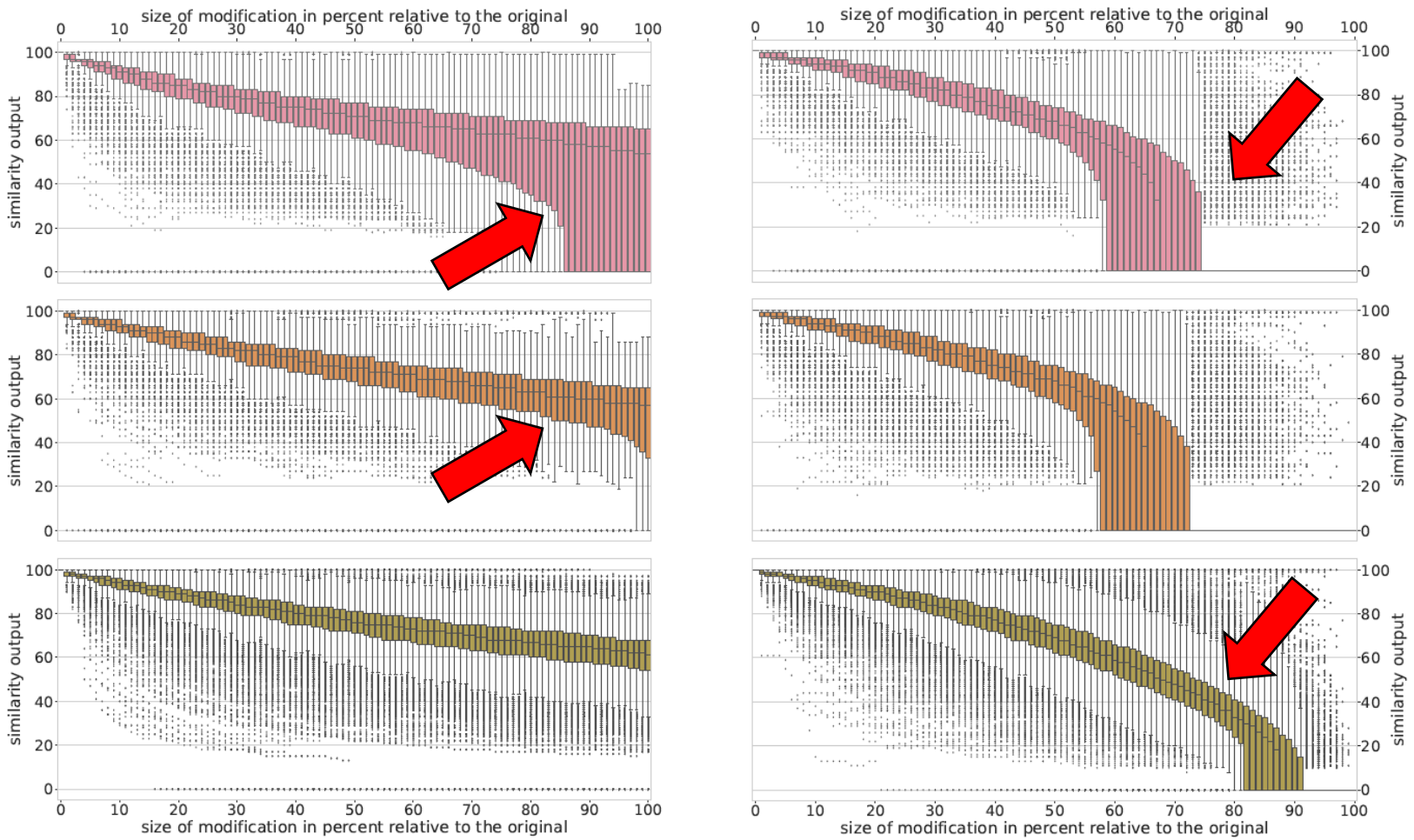
real data step-by-step corpus

- How to define accuracy and similarity?
  - The smallest error?
  - Here, variance & reliability

Evaluation – Accuracy – Real data

Insertion of bytes

Deletion of bytes



SPHF & CF

- -original
- -refactored-djb2-max
- -refactored-4b-djb2-nocommonsub

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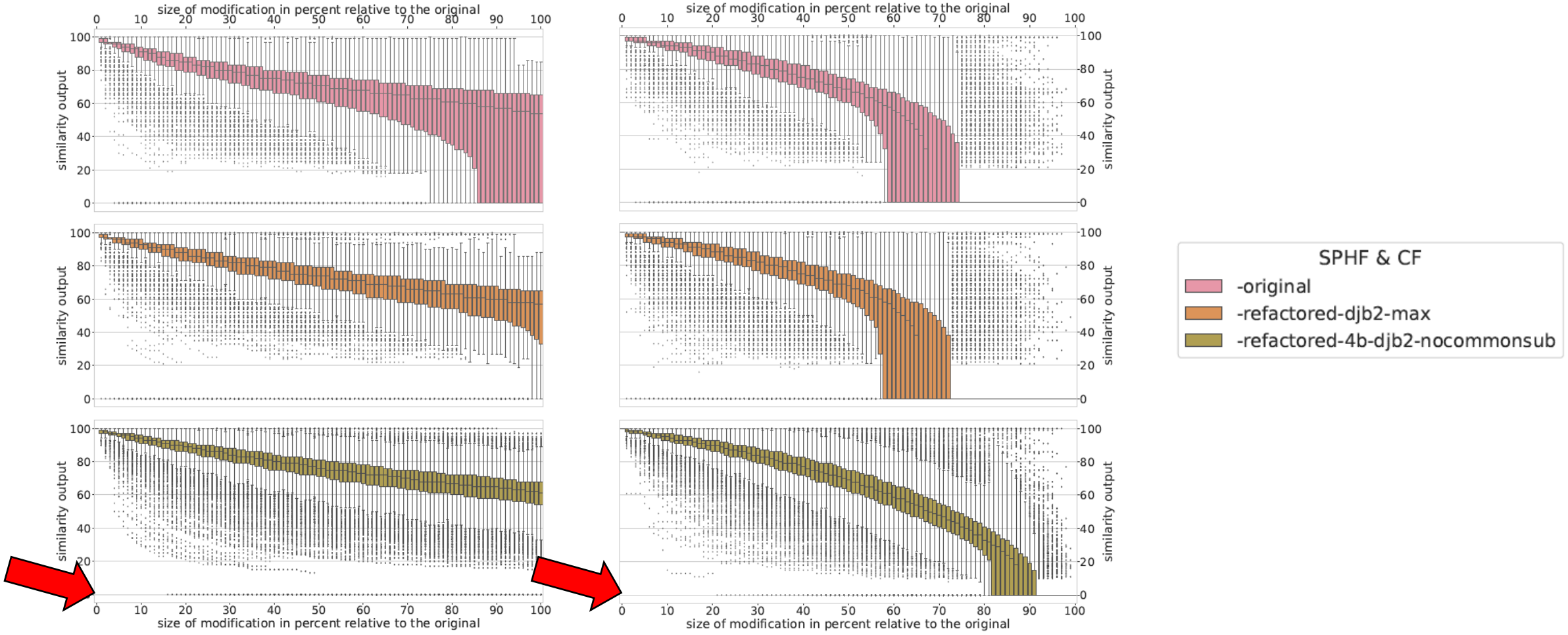
Evaluation – Accuracy – Real data

Insertion of bytes

Deletion of bytes



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Evaluation – Security

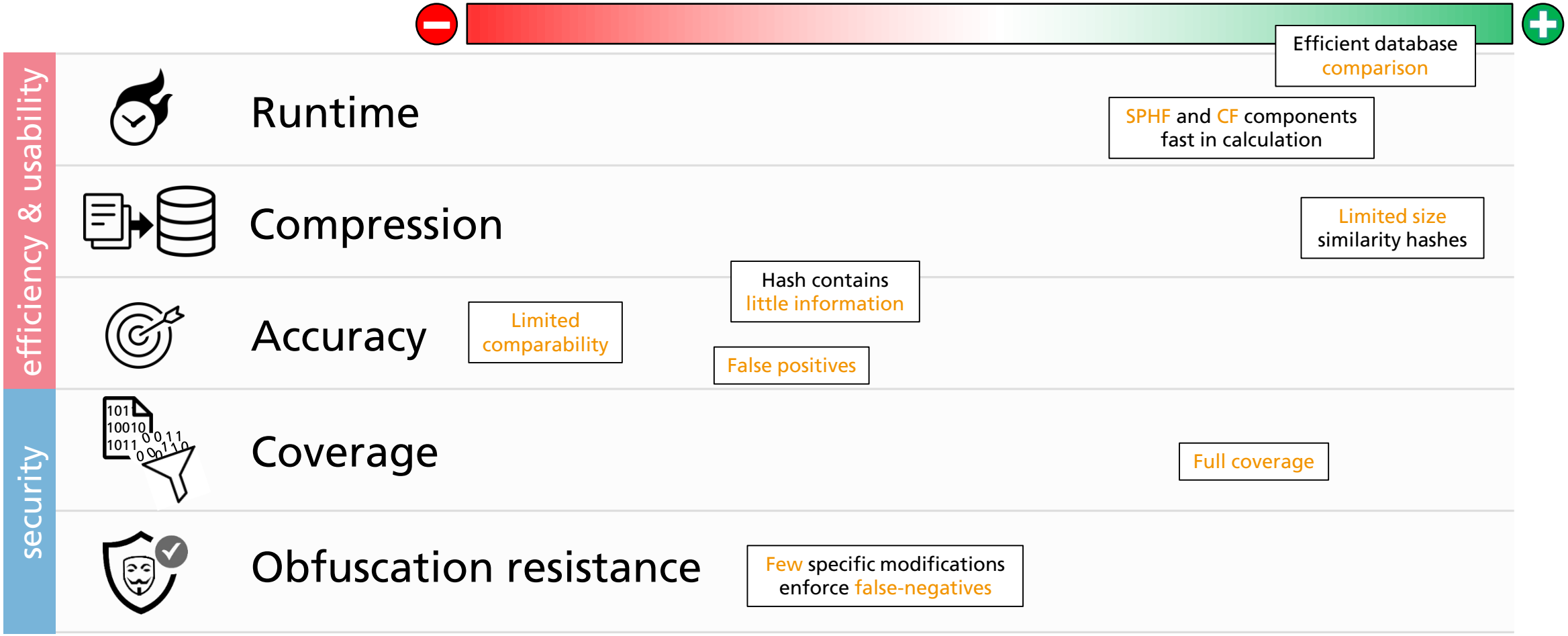
- Obfuscation resistance
  - Possibilities
    - Insertion of trigger points
    - Removal of common substrings
    - …
  - `-refactored-4b-djb2-nocommonsub`
    - Longer hash values, yet not really secure

Evaluation – Security

- Obfuscation resistance
  - Possibilities
    - Insertion of trigger points
    - Removal of common substrings
    - …
  - `-refactored-4b-djb2-nocommonsub`
    - Longer hash values, yet not really secure

- Coverage
  - `-bugfix` & `-refactored`

Evaluation – Summary – ssdeep



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Evaluation – Summary – `ssdeep-refactored-djb2-nomax`

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Evaluation – Summary – `ssdeep-refactored-djb2-nomax`

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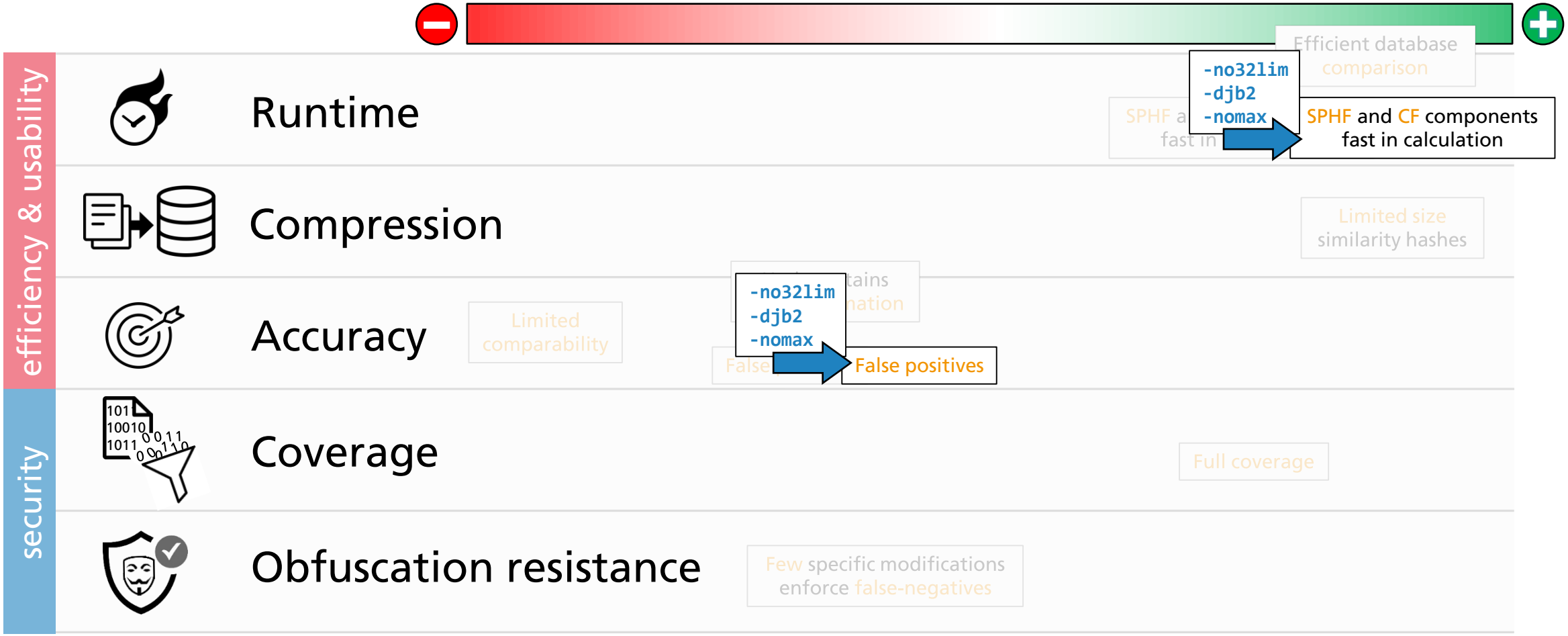
Evaluation – Summary –
ssdeep-refactored-djb2-nomax



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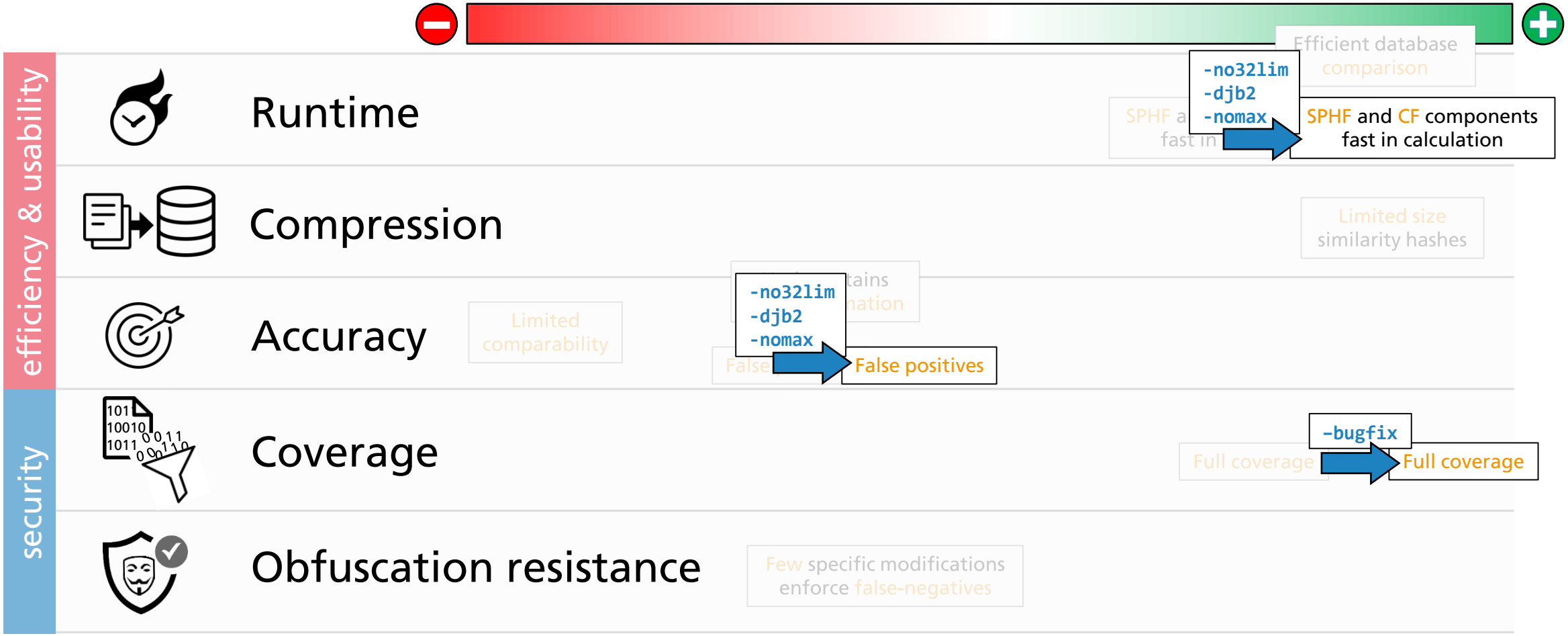
Evaluation – Summary – `ssdeep-refactored-djb2-nomax`



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Evaluation – Summary –
ssdeep-refactored-4b-djb2-nocommonsub

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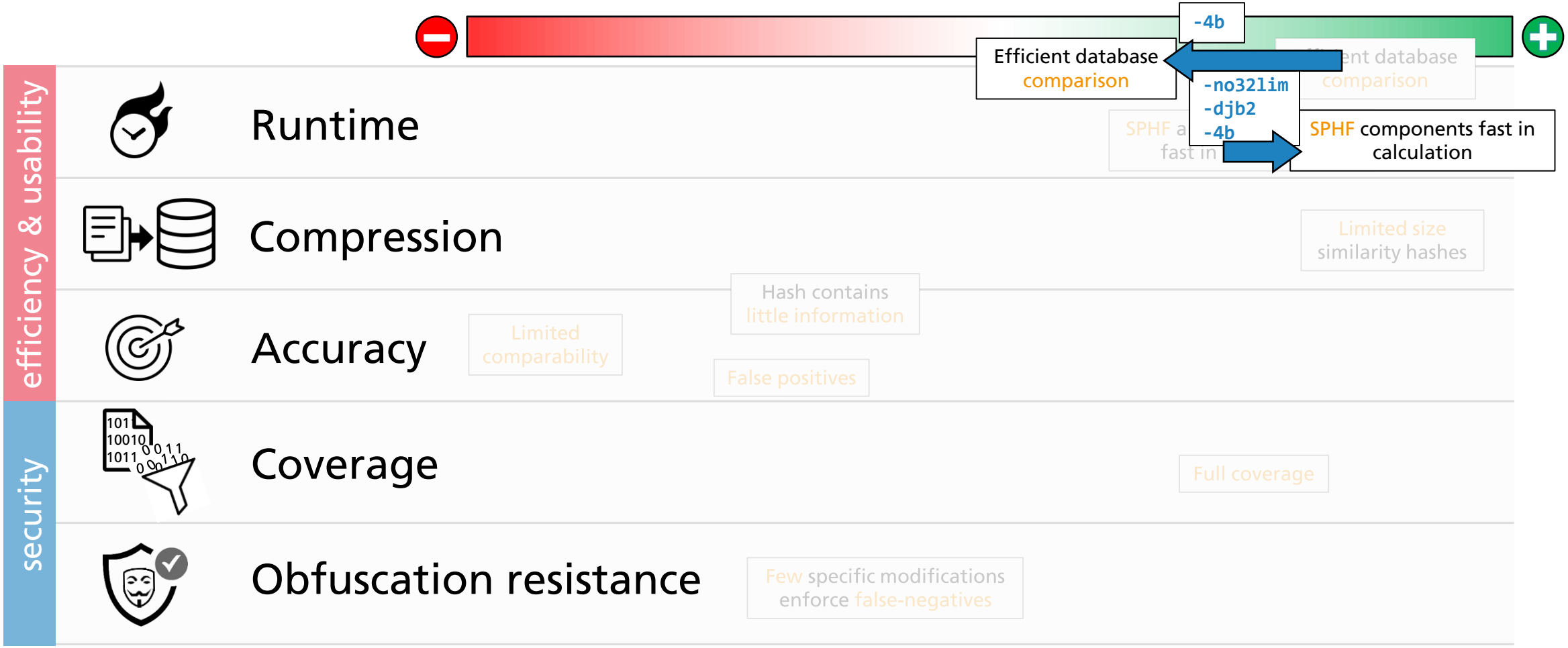

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Evaluation – Summary –
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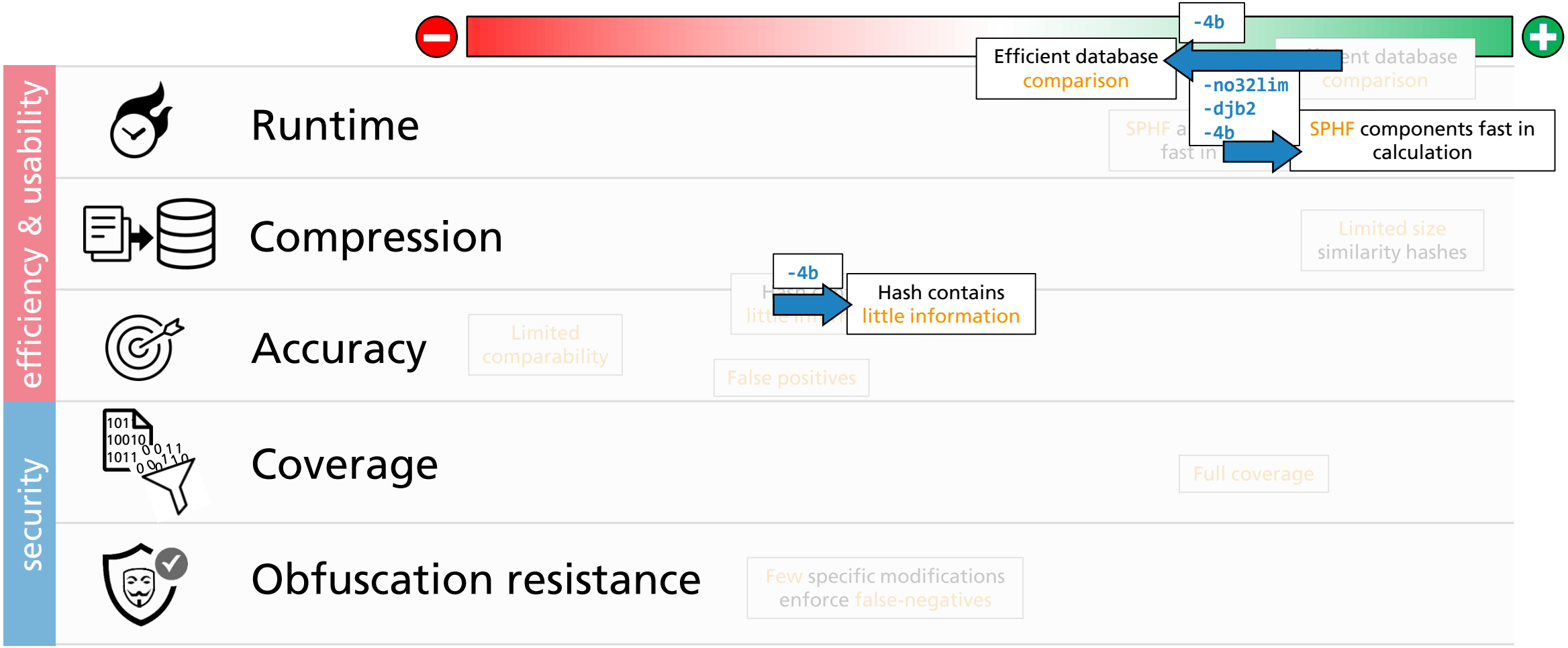

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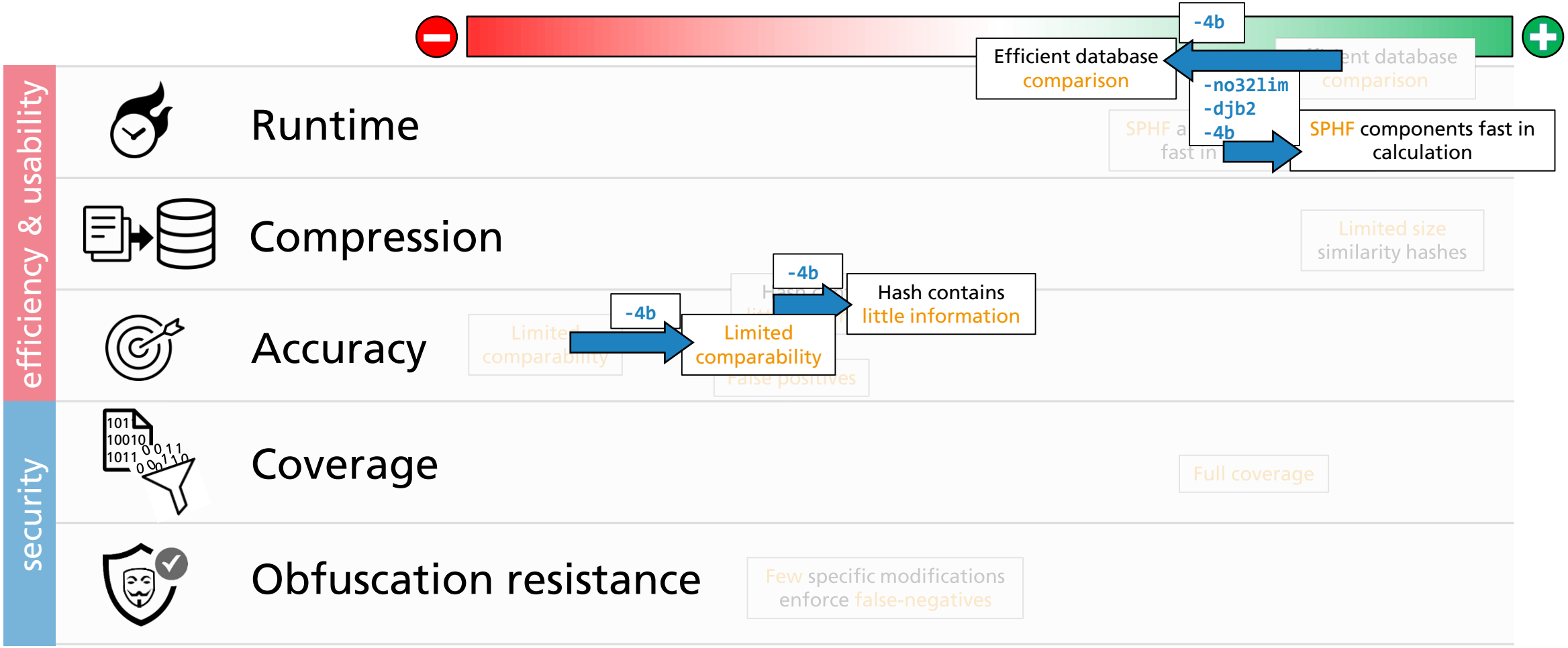
Evaluation – Summary –
ssdeep-refactored-4b-djb2-nocommonsub



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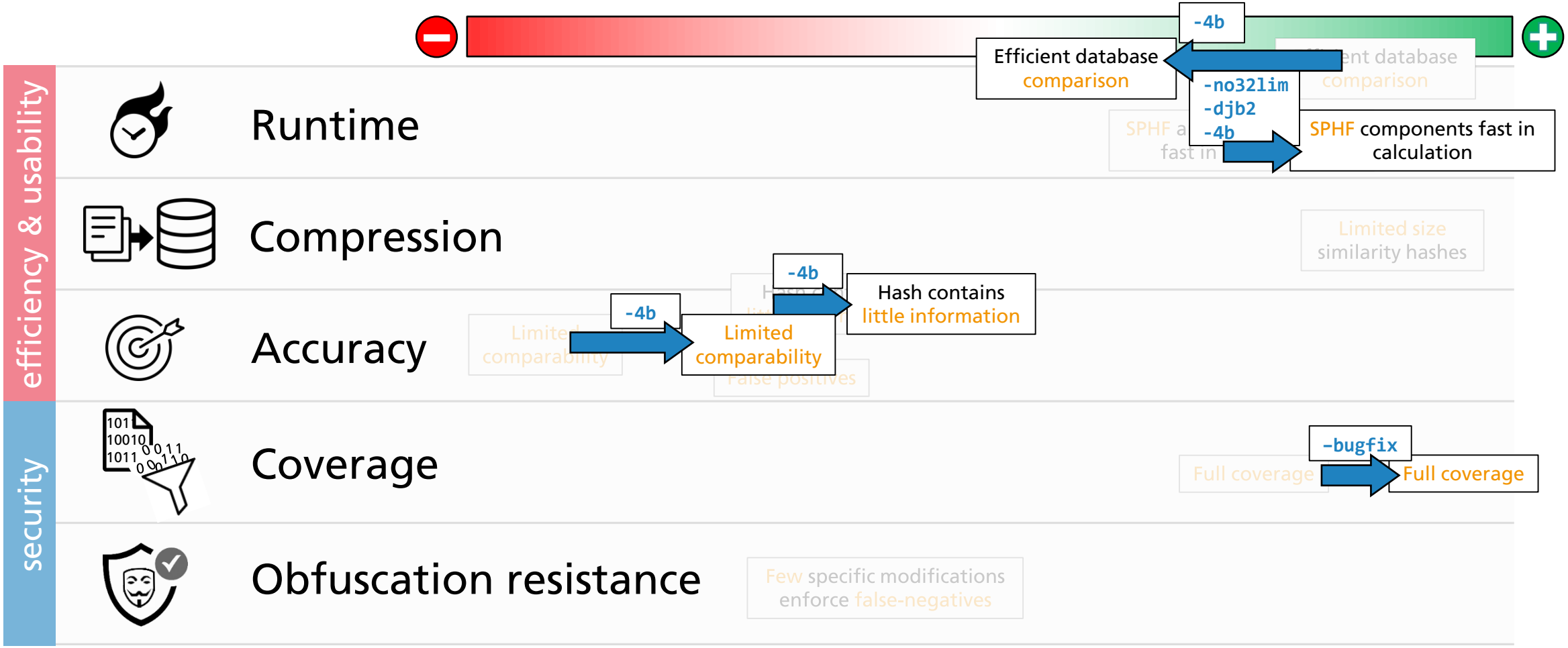
Evaluation – Summary –
ssdeep-refactored-4b-djb2-nocommonsub



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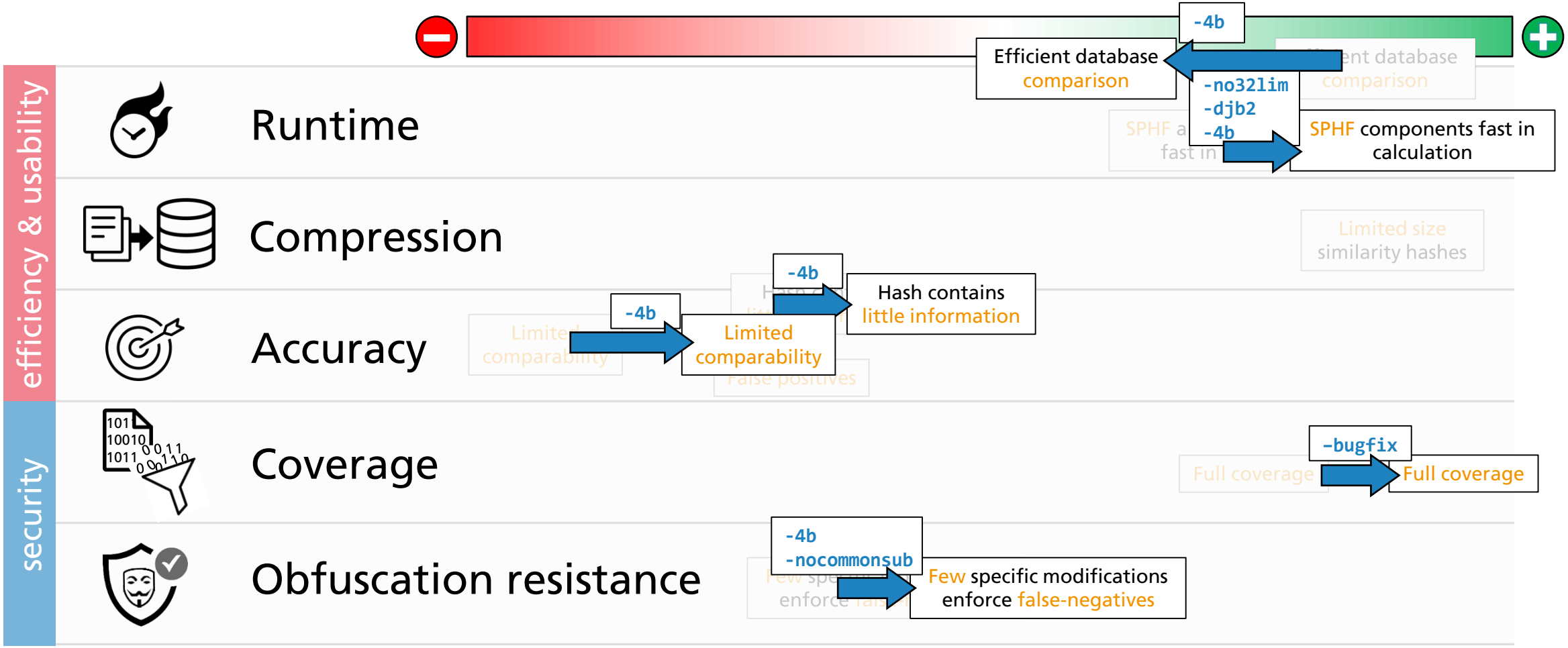
Evaluation – Summary –
ssdeep-refactored-4b-djb2-nocommonsub



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Conclusion

- Assessment and Evaluation of
  - ssdeep
  - proposed modifications
- Publicly available:
  - Modifications and Implementations
  - Data corpus
  - Evaluation results and scripts
  - Files highlighting issues

- `ssdeep-refactored-djb2-nomax`
  - More efficient SPHF and CF
  - Fewer false positives
  - Use case: Filtering and minimizing extraneous data

- `ssdeep-refactored-4b-djb2-nocommonsub`
  - Slower but larger range of comparisons
  - More efficient SPHF
  - Fewer false negatives
  - Use case: Detection of modified suspicious files

Thank you!

Any Questions?

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Code and data

https://github.com/fkie-cad/ssdeeper

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