Universität Hamburg
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Comparison of Clang Abstract Syntax Trees using String Kernels

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Raul Torres, Julian M. Kunkel, Manuel F. Dolz, Thomas Ludwig

Agenda

1. Motivation
2. Background
   - Intermediate representations
   - String kernels
3. Proposed solution
   - Creating strings from ASTs
   - Finding similarities with a novel string kernel
4. Evaluation
   - Experiment configuration
   - Blended spectrum kernel
   - Kast spectrum kernel
   - Kast1 spectrum kernel
5. Conclusions and future work

1. Motivation

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  - Detect plagiarism.

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What to compare? source code? intermediate representations? binary code? I/O access patterns?

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  - *Hybrid IRs*: Hybrid IRs combine elements of the previous two categories.
- Complex compiler infrastructures might work with different interconnected IRs, some of them closer to the source code, others closer to the machine instruction level.

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How to compare these data structures? direct tree comparison? flatten into strings? extract attribute set?

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- String kernels can be intuitively understood as functions measuring the similarity of pairs of strings.
- The more similar two strings A and B are, the higher the value of a string kernel $K(A, B)$ will be.
- In particular, string kernels check the number of shared substrings among a collection of strings.

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What is our contribution?

3. Proposed solution

Overview

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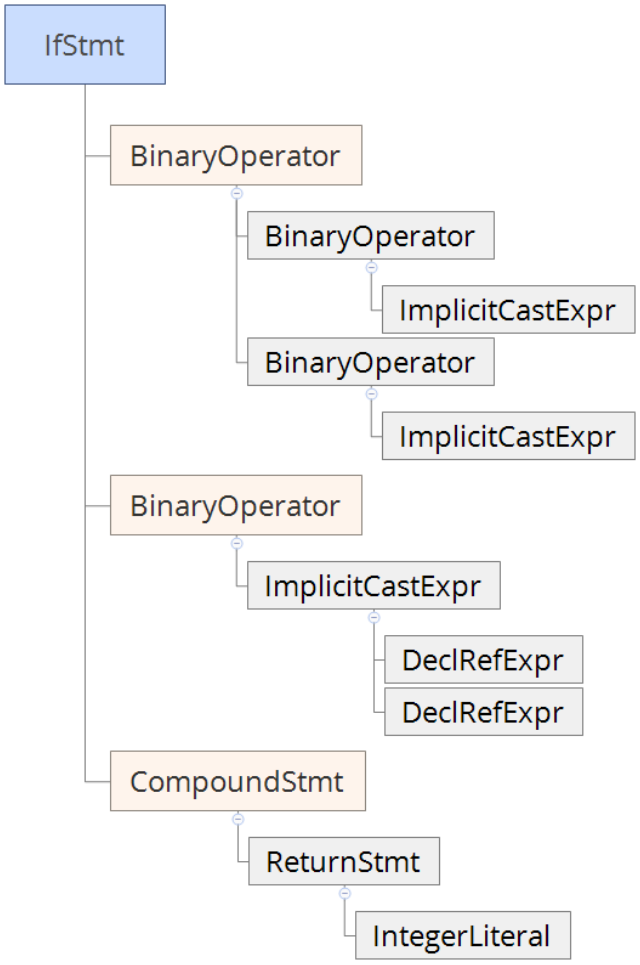
This work extends previous research from the authors, where they proposed a string kernel for the detection of patterns in I/O traces

- *"A novel string representation and kernel function for the comparison of I/O access patterns," in Parallel Computing Technologies*.

From trees to strings

a) AST.



b) Extracted tokens.

Tokens	Repetitions
[IfStmt]	1
[BinaryOperator]	1
[BinaryOperator]	1
[ImplicitCastExpr]	1
[LEVEL_UP]	2
[BinaryOperator]	1
[ImplicitCastExpr]	1
[LEVEL_UP]	3
[BinaryOperator]	1
[ImplicitCastExpr]	1
[DeclRefExpr]	1
[LEVEL_UP]	1
[DeclRefExpr]	1
[LEVEL_UP]	3
[CompoundStmt]	1
[ReturnStmt]	1
[IntegerLiteral]	1
[LEVEL_UP]	4

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4. Compress in pairs:
   - $[\texttt{IntegerLiteral}]_1\,[\texttt{LEVEL\_UP}]_5\,[\texttt{IntegerLiteral}]_1\,[\texttt{LEVEL\_UP}]_2$
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     $[\texttt{IntegerLiteral}]_2\,[\texttt{LEVEL\_UP}]_7$

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KastX spectrum kernel family

An example with cut weight = 4

a) S_1 is the largest substring found on both examples.

A_{64} = a_3 b_2 c_4 d_2 e_1 f_5 g_1 h_1 i_1 j_2 k_1 l_3 m_1 n_2 f_3 g_1 h_2 o_1 p_1 q_1 r_2 s_1 t_5 u_9 b_7 c_2

19

17 18

B_{52} = v_2 a_5 b_1 c_1 d_3 e_1 f_4 g_1 h_1 w_2 x_2 y_1 a_1 b_2 c_6 d_1 e_3 f_1 g_1 h_3 z_1 b_5 c_1 f_1 g_1 h_1

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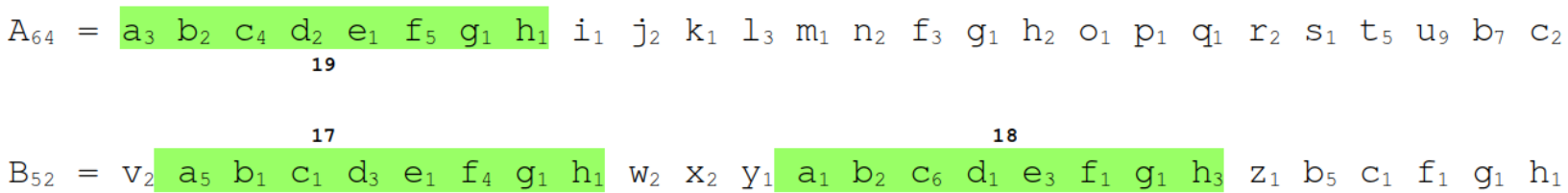
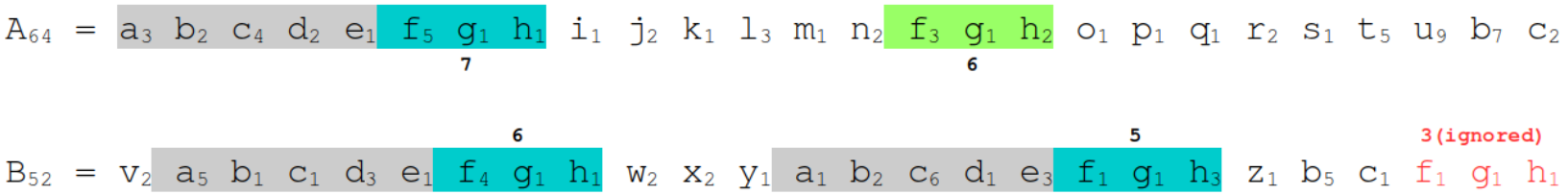


b) S_2 appears once as an independent case.



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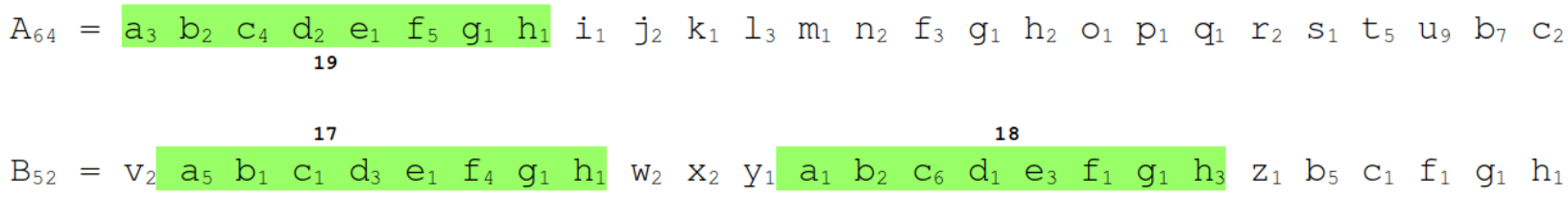

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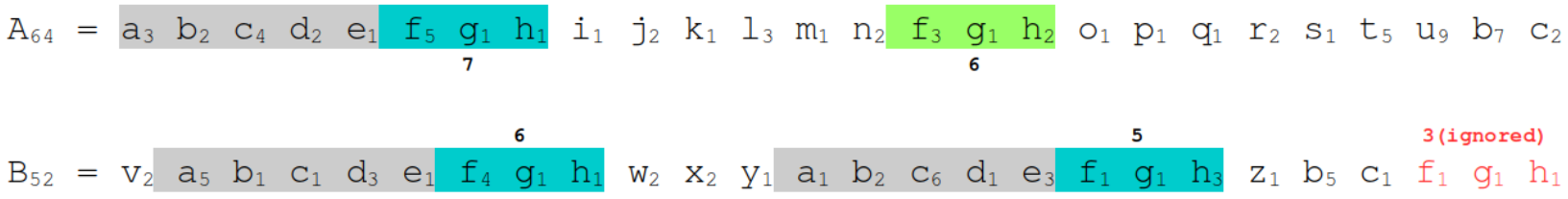
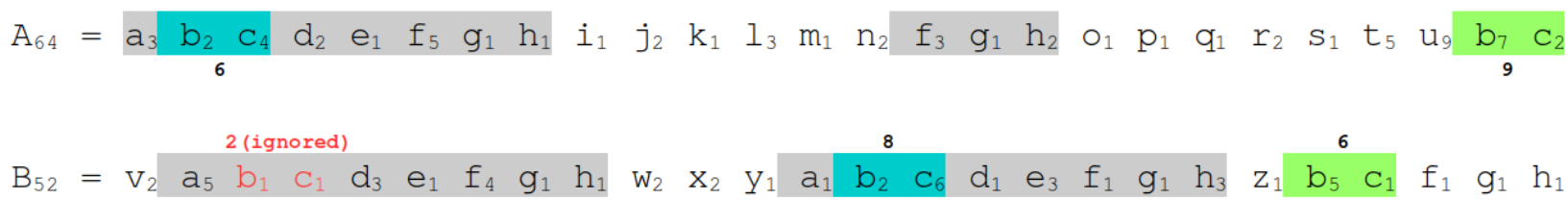


c) S_3 appears twice as an independent case.



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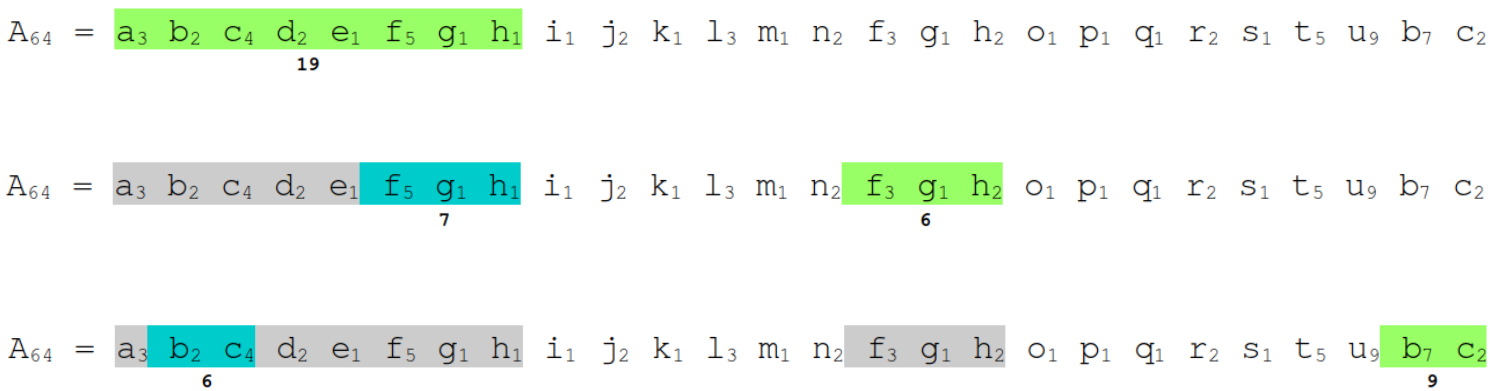
- The similarity value corresponds to the inner product of the new feature vectors of A and B.
- This kernel uses only the weight of the *independent* valid matching substrings.
- If the string does not present an independent occurrence of a particular valid matching substring, the feature value is set to 1, to avoid zero values when calculating the inner product.

Kast1 spectrum kernel: an example (I)

New feature vector for A



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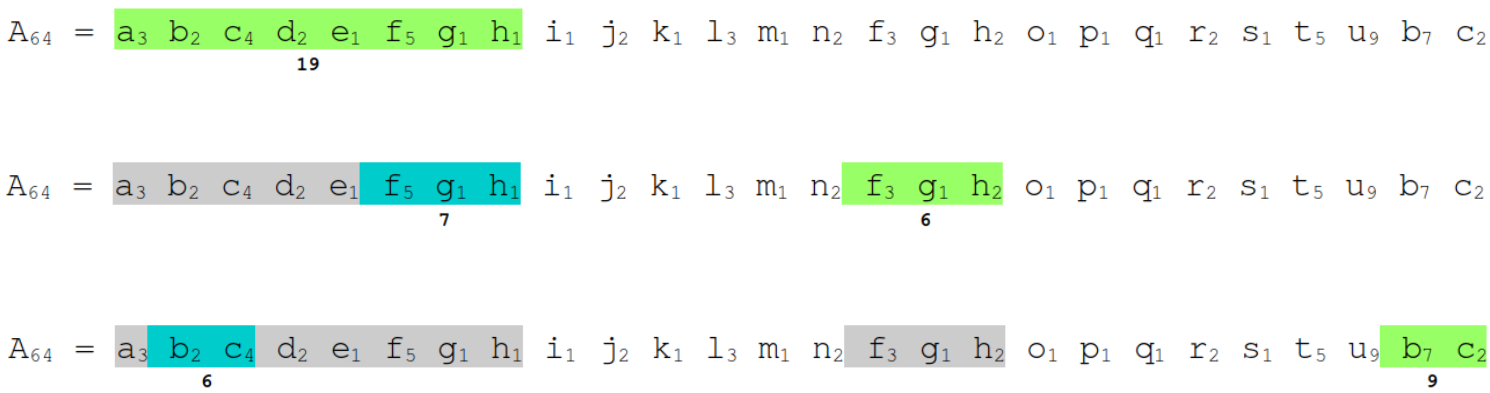

$$weight\_k1_{w \geq 4}(S_1)_A = 19 \tag{1}$$

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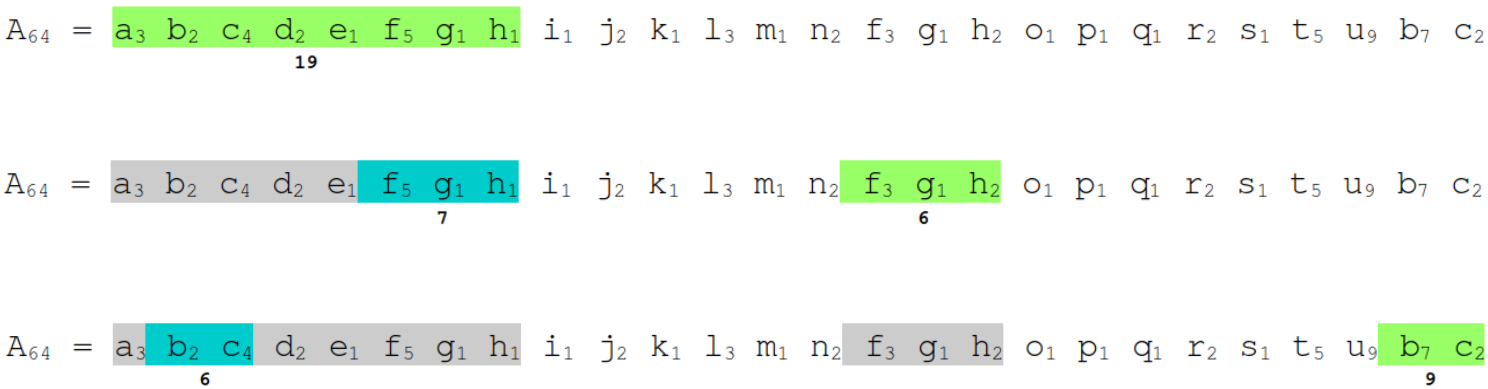

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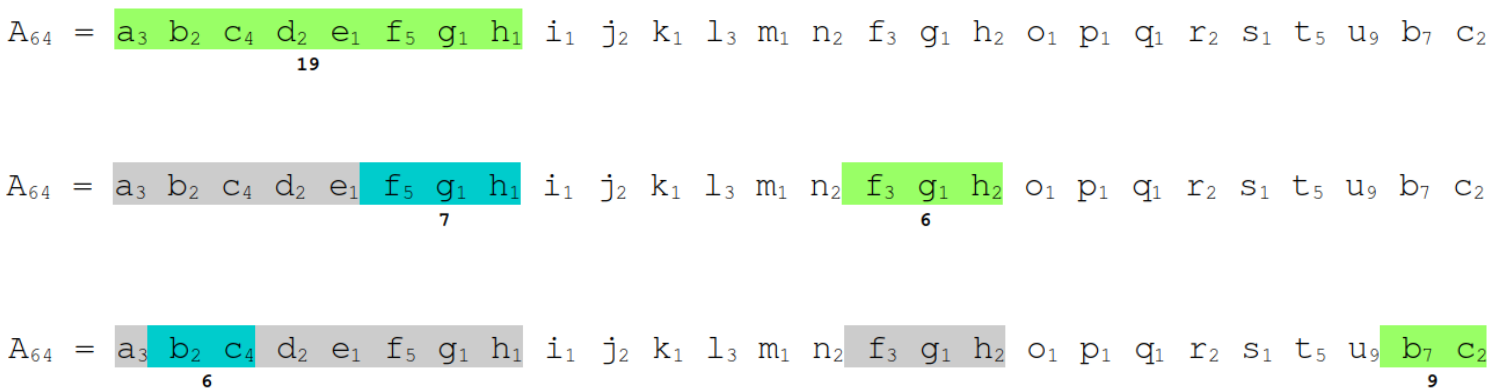

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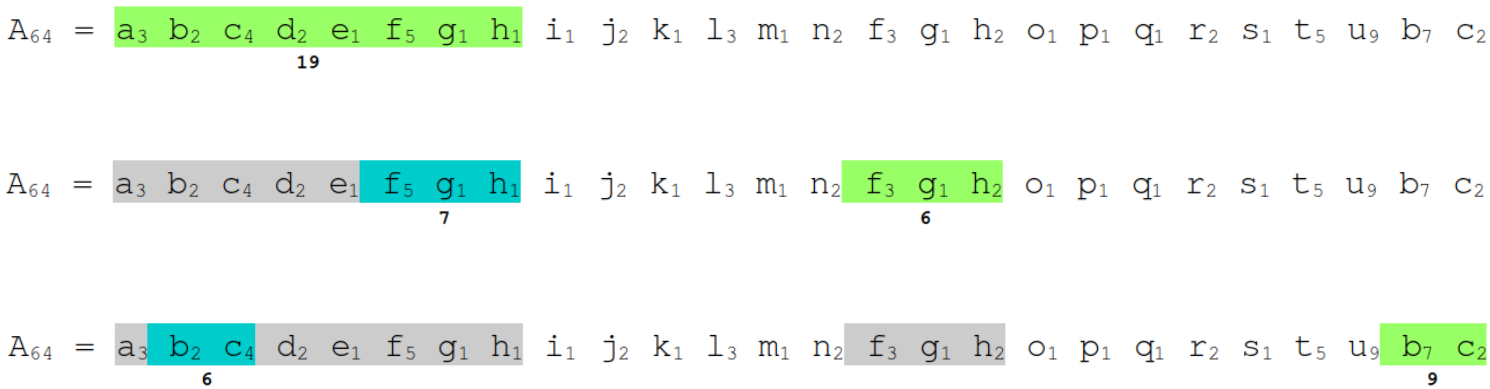

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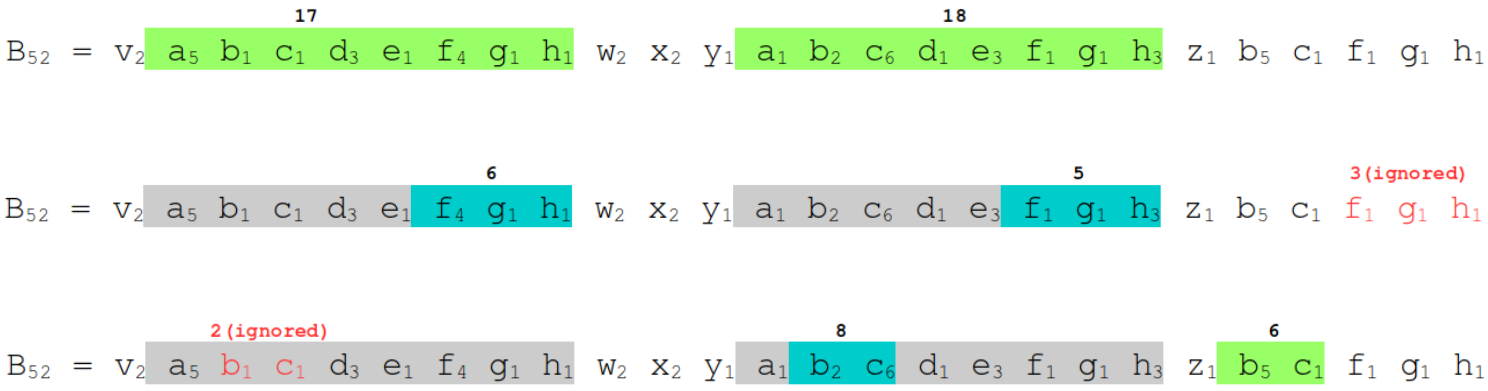
$$f1_{w\geq 4}(A) = \{19, 6, 9\} \tag{4}$$

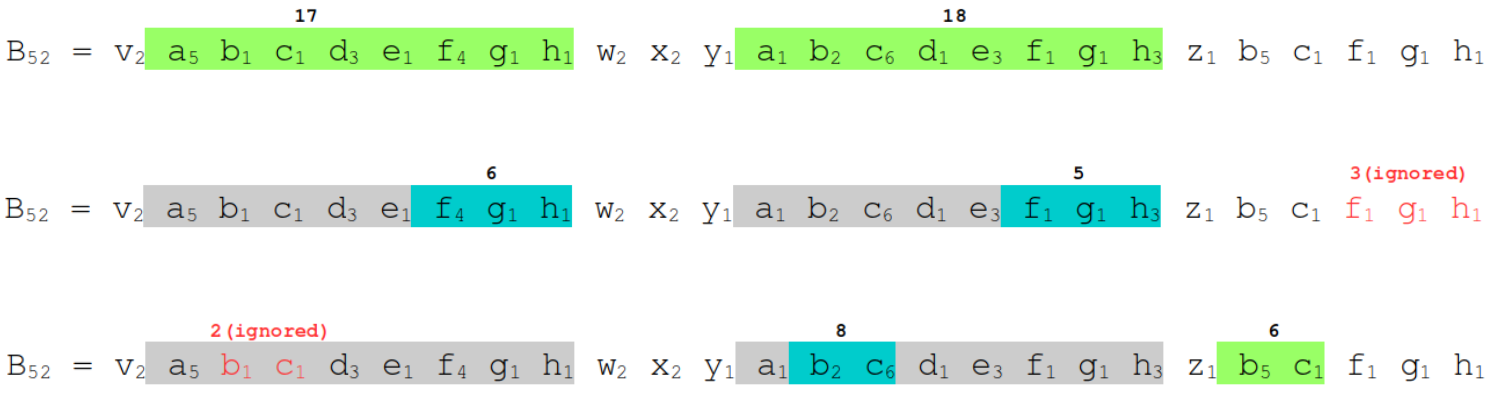
Kast1 spectrum kernel: an example (II)

New feature vector for B



Kast1 spectrum kernel: an example (II)

New feature vector for B



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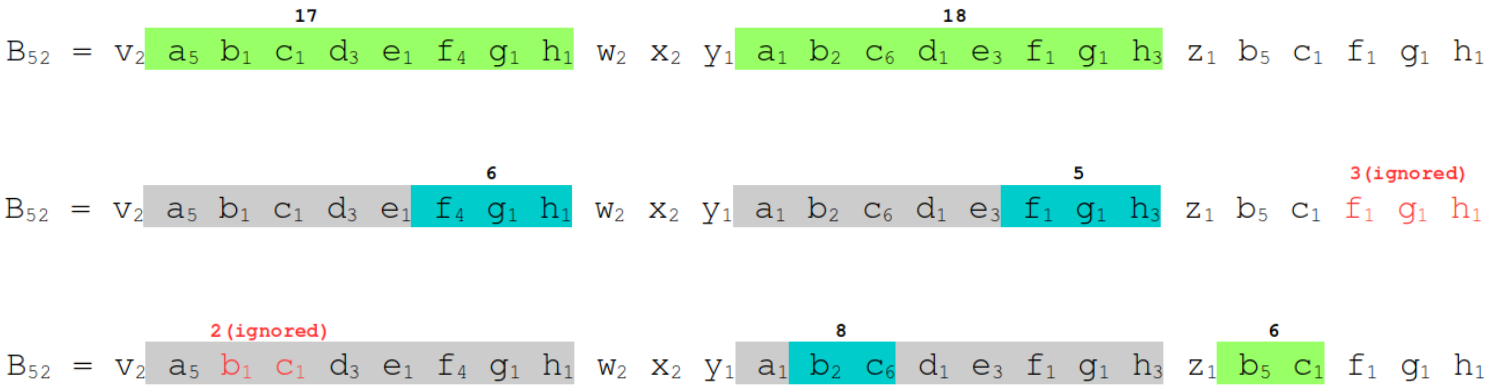

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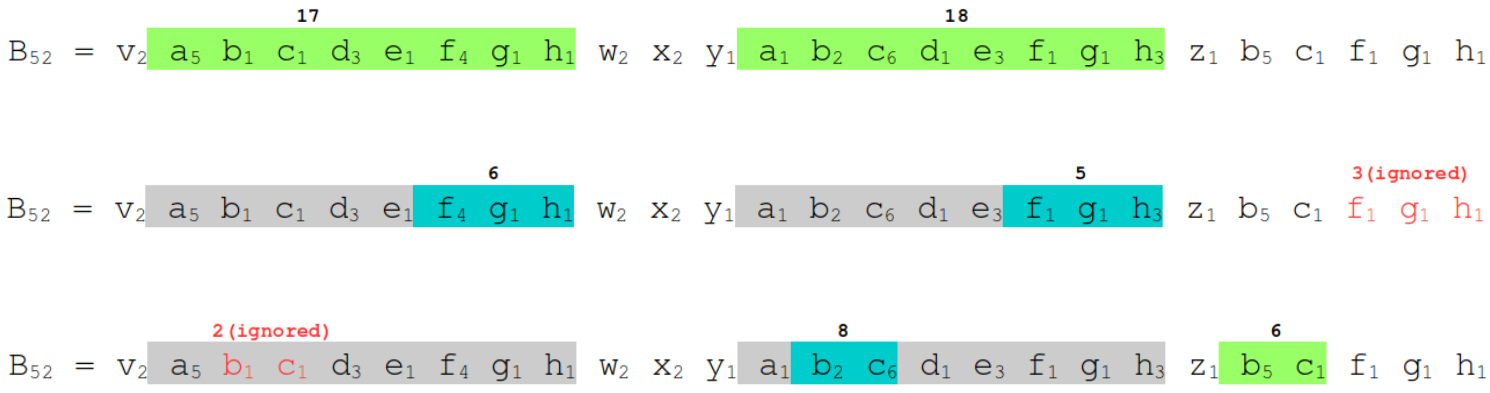

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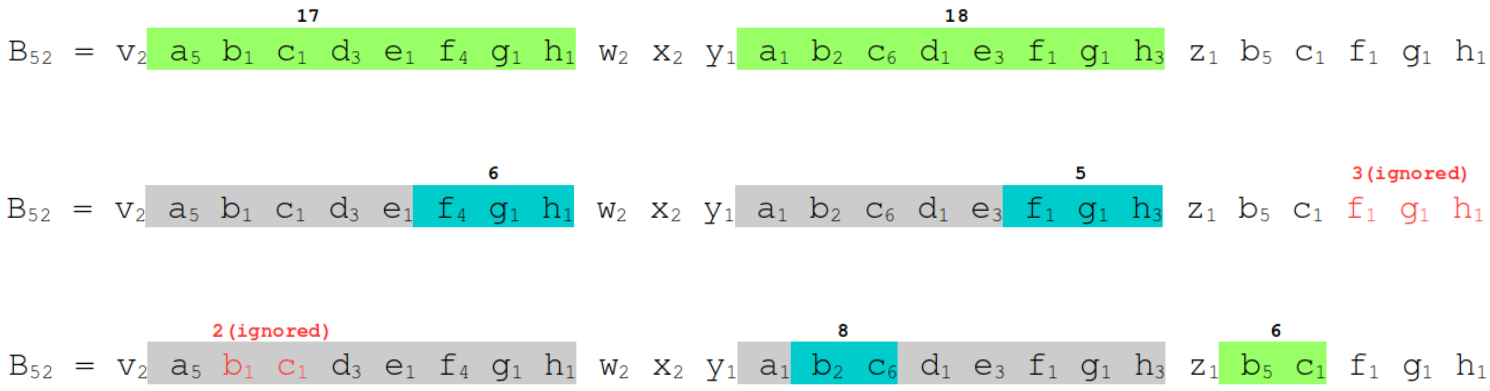

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Kast1 spectrum kernel: an example (III)

Similarity calculation

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According to this kernel, Strings A and B are approximately 21.78% similar.

4. Evaluation

Code samples (I)

20 functions X 5 versions(Original, Type-1, Type-2, Type-3 and Type-4 clones) classified as follows:

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Code samples (II)

- (C) 3D stencils.

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  - Vertex stencil.
  - Non-compact stencil 1 layer.

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  - Non-compact stencil 1 layer.
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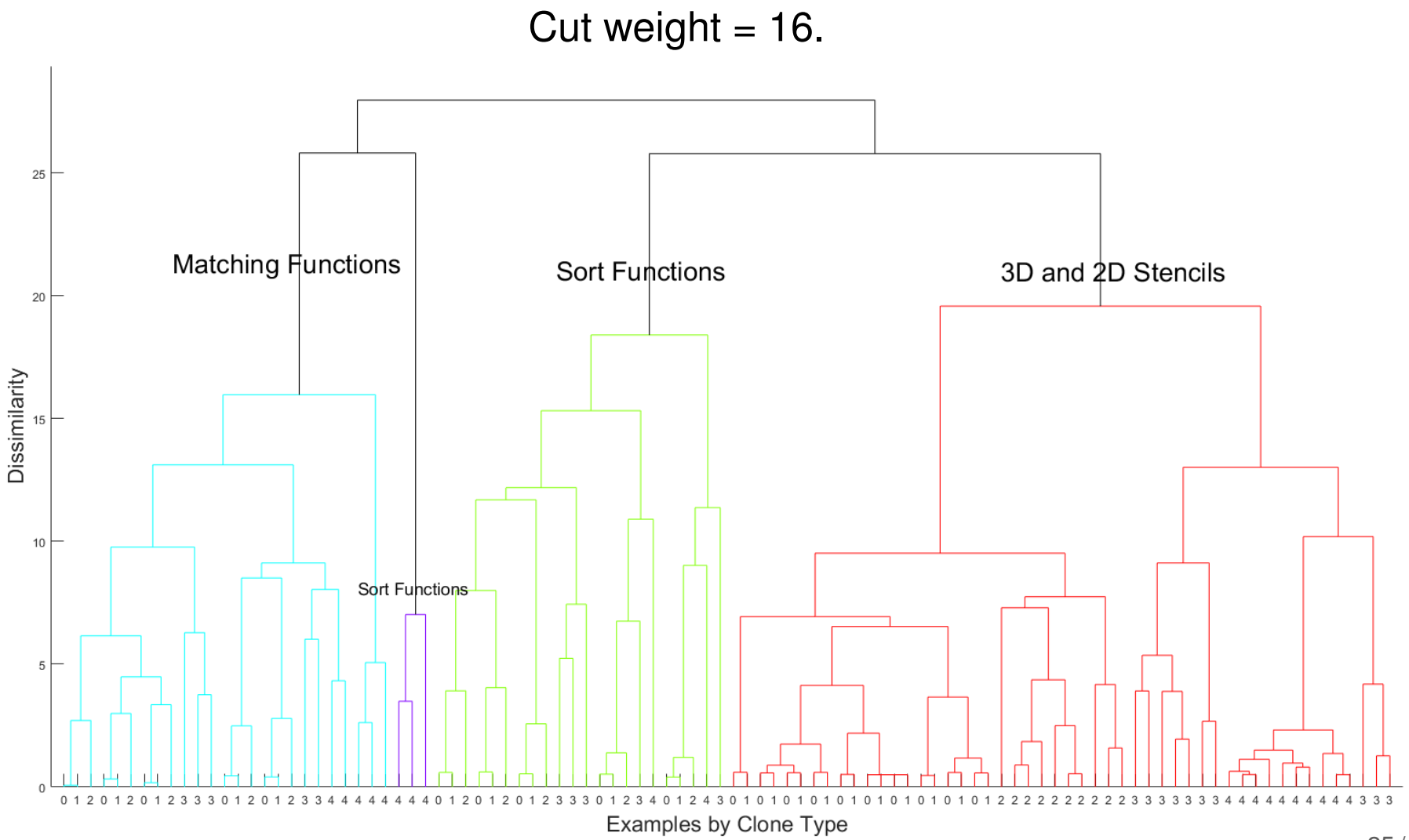
  - Non-compact stencil 1 layer.
  - Non-compact stencil 2 layers.

Other setups

- The selected cut weight values were the following:
  - $\{2^0, 2^1, ..., 2^k\} : k = 9$.
- The clustering algorithm here used was:
  - Hierarchical Clustering.

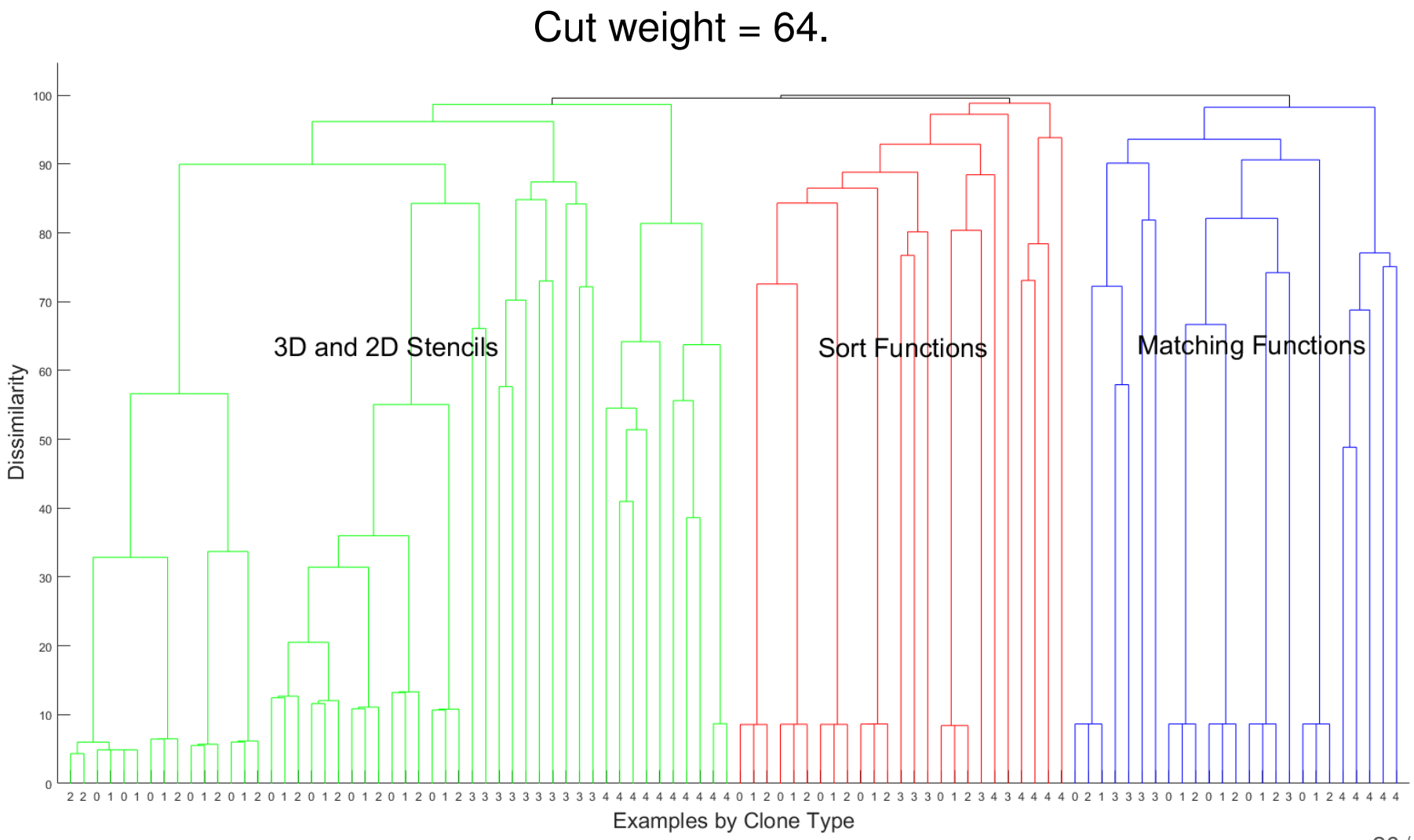
Baseline kernel 1

Blended spectrum kernel



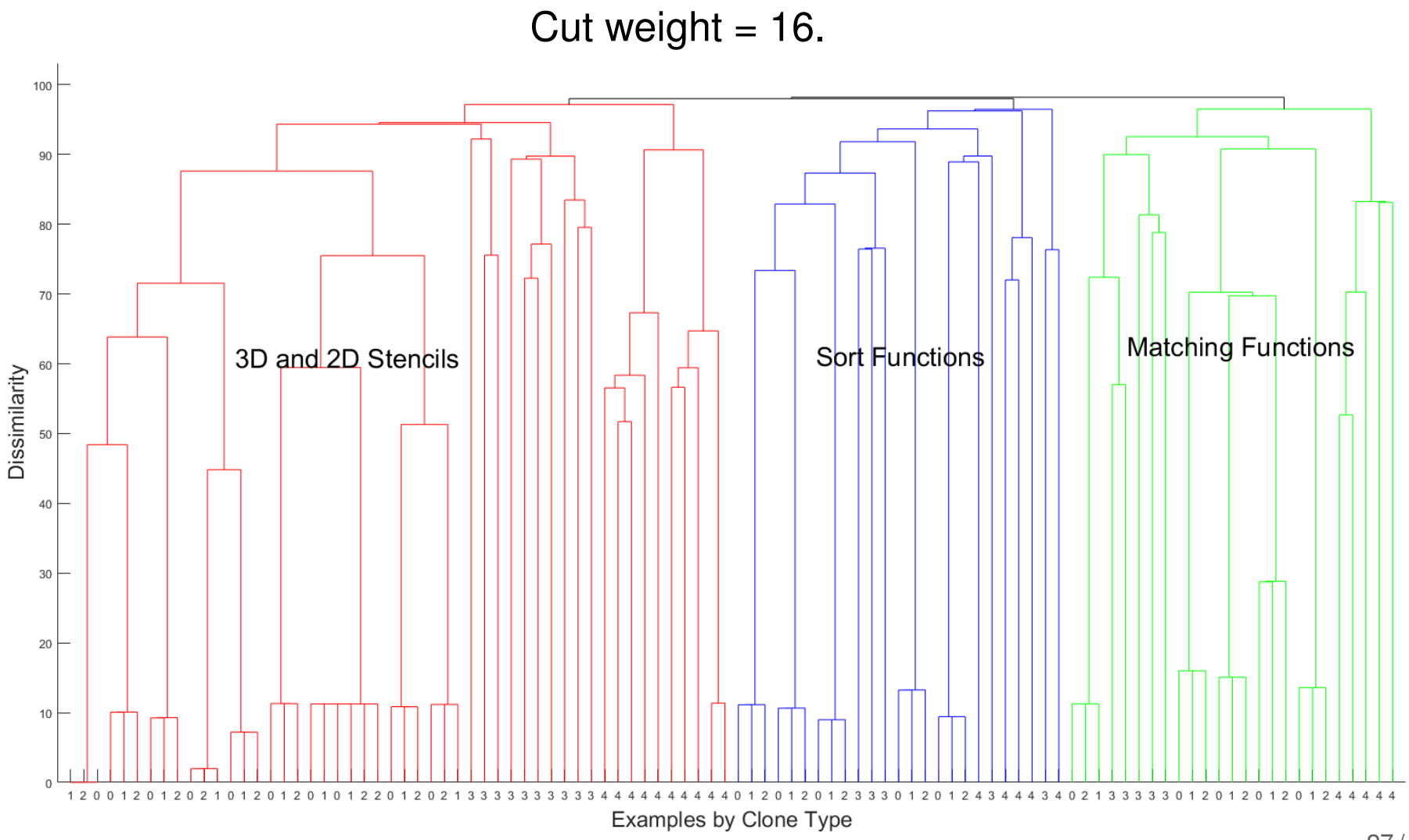
Baseline kernel 2 (previous work)

Kast spectrum kernel



Proposed kernel

Kast1 spectrum kernel



5. Conclusions and Future Work

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- They showed a consistent formation of three clusters: matching functions, sorting functions and stencils (3D and 2D).
- They yielded better results than the *blended spectrum kernel* as the clustering showed no misplaced examples.
- This indicates that this novel comparison method can be promisingly utilized to find similarities in source code snippets.

Future work

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- Study the linear intermediate representation delivered by the LLVM Compiler Infrastructure.

Thanks!