

# A Heuristic Solution to the Closest String Problem Using Wave Function Collapse Techniques

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The Closest String problem (CSP) is an NP-Complete problem which seeks to find the geometrical center of a set of input strings: given  $k$  strings of length  $L$  and a non-negative integer  $d$ , construct a solution string  $t$ , if it exists, such that the Hamming distance between  $t$  and each input string is no larger than  $d$ . This project proposes WFC-CSP, a novel heuristic algorithm inspired by Wave Function Collapse (WFC) techniques to solve CSP. Experimental results show that the WFC-CSP algorithm is highly reliable and efficient. The single iteration complexity of WFC-CSP is tractable with respect to number of strings  $k$ , string length  $L$ , and the alphabet size. Furthermore, the target maximum Hamming distance  $d$  does not affect the algorithm's complexity within an iteration. As more iterations are allowed, WFC-CSP's success rate of finding solution strings that satisfy the maximum Hamming distance requirement increases. In comparison to the Fixed-Parameter algorithm (FP-CSP) Gramm et al. proposed in "Fixed-parameter algorithms for closest string and related problems," the WFC-CSP algorithm is significantly faster when  $d$  is larger or equal to 16, while FP-CSP's runtimes become unviable. When compared to an Ant Colony Optimization-based metaheuristic approach to CSP (Ant-CSP) that Faro et al. proposed in "Ant-CSP: An ant colony optimization algorithm for the closest string problem," WFC-CSP offers a consistently higher success rate in finding solution strings, and, in many cases, also has a faster run time. The Closest String Problem has wide applications in the fields of computational biology and coding theory.

## Awards Won:

Second Award of \$2,000

American Mathematical Society: Third Award of \$500

Mu Alpha Theta, National High School and Two-Year College Mathematics Honor Society: First Award of \$ 1,500