

How to Compress the Solution

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Abstract

We provide an upper bound on the compression size of solutions to the graph coloring problem. In general, if solutions to a combinatorial problem exist with high probability and the probability is simple, then there exists a simple solution to the problem. Otherwise the problem instance has high mutual information with the halting problem.

Results

$\mathbf{K}(x|y)$ is the conditional prefix Kolmogorov complexity. Algorithmic probability is $\mathbf{m}(x) = \{2^{-\|p\|} : U(p) = x\}$, where U is the universal Turing machine. For set $D \subseteq \{0,1\}^*$, computable probability P , $O(1)\mathbf{m}(D) > 2^{-\mathbf{K}(P)}P(D)$. $\mathbf{I}(a; \mathcal{H}) = \mathbf{K}(a) - \mathbf{K}(a|\mathcal{H})$, where \mathcal{H} is the halting sequence. $<^+ f$ is $< f + O(1)$ and $<^{\log} f$ is $< f + O(\log(f+1))$.

Lemma 1 ([Eps22]) *For partial computable $f : \mathbb{N} \rightarrow \mathbb{N}$, for all $a \in \mathbb{N}$, $\mathbf{I}(f(a); \mathcal{H}) <^+ \mathbf{I}(a; \mathcal{H}) + \mathbf{K}(f)$.*

Theorem 1 ([Lev16, Eps19])

For finite $D \subset \{0,1\}^$, $-\log \max_{x \in D} \mathbf{m}(x) <^{\log} -\log \sum_{x \in D} \mathbf{m}(x) + \mathbf{I}(D; \mathcal{H})$.*

For graph $G = (V, E)$, with undirected edges, a k -coloring is a function $f : V \rightarrow \{1, \dots, k\}$ such that if $(v, u) \in E$, then $f(v) \neq f(u)$.

Theorem 2 *For graph $G = (V, E)$, $|V| = n$ with max degree d , there is a k coloring f , with $\mathbf{K}(f) <^{\log} \mathbf{K}(n, k) - n \log(1 - d/k) + \mathbf{I}((G, k); \mathcal{H})$.*

Proof. Let us say we randomly assign a color to each vertex. The probability that the color of the i th vertex does not conflict with the previous coloring is at least $(k - d)/k$. Thus the probability of a proper coloring is $\geq ((k - d)/k)^n$. Let $D \subseteq \{0,1\}^{n \lceil \log k \rceil}$ be all encoded proper k colorings of G . $\mathbf{K}(D|G, k) = O(1)$. Let $P : \{0,1\}^* \rightarrow \mathbb{R}_{\geq 0}$ be a probability measure that is the uniform distribution over all possible color assignments. Thus

$$-\log P(D) <^{\log} -n \log(1 - d/k).$$

Thus by Theorem 1 and Lemma 1, there is a coloring $f \in D$ with

$$\begin{aligned} \mathbf{K}(f) &<^{\log} -\log \mathbf{m}(D) + \mathbf{I}(D; \mathcal{H}) \\ &<^{\log} \mathbf{K}(P) - \log P(D) + \mathbf{I}(D; \mathcal{H}) \\ &<^{\log} \mathbf{K}(n, k) - n \log(1 - d/k) + \mathbf{I}((G, k); \mathcal{H}). \end{aligned}$$

□

References

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- [Lev16] L. A. Levin. Occam bound on lowest complexity of elements. *Annals of Pure and Applied Logic*, 167(10):897–900, 2016.

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