A Short Proof on the Existence of Anomalies

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Abstract

The Independence Postulate (IP) is a finitary Church-Turing Thesis, postulating that mathematical sequences are independent from physical ones. IP implies the existence of anomalies.

Anomalies

$\mathbf{K}(x|y)$ is the conditional prefix Kolmogorov complexity. For probability p over $\mathbb{N}$, randomness deficiency is $\mathbf{d}(a|p) = \lfloor -\log p(a) \rfloor - \mathbf{K}(a)$. $\mathbf{I}(a;\mathcal{H}) = \mathbf{K}(a) - \mathbf{K}(a|\mathcal{H})$, where $\mathcal{H}$ is the halting sequence. An elementary probability measure over $\mathbb{N}$ has finite support and a range in $\mathbb{Q}$. $<^+ f$ is $<f+O(1)$ and $<^{\log} f$ is $<f+O(\log(f+1))$. Stochasticity is $\Lambda(a|b) = \min\{\mathbf{K}(Q|b) + 3\log\max\{\mathbf{d}(a|Q,b),1\} : Q$ is an elementary probability measure$\}$.
$\Lambda(a|b) < \Lambda(a) + O(\log \mathbf{K}(b))$. The following definition is from [Lev74] .

Definition 1 (Information) $\mathbf{I}(\alpha:\beta) = \log\sum_{x,y} 2^{\mathbf{K}(x)+\mathbf{K}(y)-\mathbf{K}(x,y)-\mathbf{K}(x|\alpha)-\mathbf{K}(y|\beta)}$.

The Independence Postulate [Lev13] statement is:

IP: *Let α be a sequence defined with an n-bit mathematical statement, and a sequence β can be located in the physical world with a k-bit instruction set. Then $\mathbf{I}(\alpha:\beta) < k + n + c$ for some small absolute constant c.*

There are many proofs in the literature that stochastic numbers have high mutual information with the halting sequence. One such detailed proof is in [Eps21].

Lemma 1 $\Lambda(x) <^{\log} \mathbf{I}(x;\mathcal{H})$.

Lemma 2 *For computable probability p over $\mathbb{N}$ and for $D\subset\mathbb{N}$, $|D| = 2^s$, $s < \max_{a\in D}\mathbf{d}(a|p) + \Lambda(D) + \mathbf{K}(s) + \mathbf{K}(p) + O(\log \mathbf{K}(s)\mathbf{K}(p))$.*

Proof. We relativize the universal Turing machine to p and s. Let Q be an elementary probability measure that realizes $\Lambda(D)$. Let $d = \max\{\mathbf{d}(D|Q),1\}$. Let $F \subseteq \mathbb{N}$ be a random set where each element $a \in \mathbb{N}$ is selected independently with probability $cd2^{-s}$, where $c \in \mathbb{N}$ is chosen later. $\mathbf{E}[p(F)] \le cd2^{-s}$. Furthermore

$$\begin{aligned}&\mathbf{E}[Q(\{G : |G| = 2^s, G\cap F = \emptyset\})]\\ &\le \sum_G Q(G)(1-cd2^{-s})^{2^s} < e^{-cd}.\end{aligned}$$

Thus finite $W \subset \mathbb{N}$ can be chosen such that $p(W) \le 2cd2^{-s}$ and $Q(\{G : |G| = 2^s, G\cap W = \emptyset\}) \le e^{1-cd}$. $D\cap W \neq \emptyset$, otherwise, using the Q-test, $t(G) = e^{cd-1}$ if $(|G| = 2^s, G\cap W = \emptyset)$ and $t(G) = 0$ otherwise, we have

$$\begin{aligned}&\mathbf{K}(D|Q,d,c) <^+ -\log Q(D) - (\log e)cd\\ &\quad(\log e)cd <^+ -\log Q(D) - \mathbf{K}(D|Q) + \mathbf{K}(d,c)\\ &\quad(\log e)cd <^+ d + \mathbf{K}(d,c),\end{aligned}$$

which is a contradiction for large c. Thus there is an $a \in D\cap W$, where

$$\begin{aligned}&\mathbf{K}(a) <^+ -\log p(a) + \log d - s + \mathbf{K}(d) + \mathbf{K}(Q)\\ &\quad s <^+ \mathbf{d}(a|p) + \Lambda(D).\end{aligned}$$

Making the relativization of p and s explicit,

$$\begin{aligned}&s < -\log p(a) - \mathbf{K}(a|p,s) + \Lambda(D|p,s)\\ &s < \max_{a\in D}\mathbf{d}(a|p) + \Lambda(D) + \mathbf{K}(s) + \mathbf{K}(p)\\ &\quad + O(\log \mathbf{K}(s)\mathbf{K}(p)). \ \square\end{aligned}$$

For $\tau \in \mathbb{N}^{\mathbb{N}}$, let $\tau(n)$ be the first 2^n unique numbers found in τ. The sequence τ is assumed to have an infinite amount of unique numbers, and represents a series of observations.

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Theorem 1 *For probability p over $\mathbb{N}$ and $\tau\in\mathbb{N}^{\mathbb{N}}$, let $s_{\tau,p} = \sup_n \big(n - 3\mathbf{K}(n) - \max_{a\in\tau(n)} \mathbf{d}(a|p)\big)$. Then $s_{\tau,p} <^{\log} \mathbf{I}(\langle\tau\rangle : \mathcal{H}) + \mathbf{K}(p)$.*

Proof. By Lemmas 1 and 2, and the fact that $\mathbf{I}(x;\mathcal{H}) <^{+} \mathbf{I}(\alpha : \mathcal{H}) + \mathbf{K}(x|\alpha)$,

$$
\begin{aligned}
&n < \max_{a\in\tau(n)} \mathbf{d}(a|p) + \mathbf{I}(\tau(n);\mathcal{H}) + \mathbf{K}(p) + \mathbf{K}(n)\\
&\quad + O(\log \mathbf{I}(\tau(n);\mathcal{H})\mathbf{K}(p)\mathbf{K}(n)),\\
&n < \max_{a\in\tau(n)} \mathbf{d}(a|p) + 2\mathbf{K}(n) + \mathbf{I}(\langle\tau\rangle : \mathcal{H}) + \mathbf{K}(p)\\
&\quad + O(\log \mathbf{I}(\langle\tau\rangle : \mathcal{H})\mathbf{K}(p)\mathbf{K}(n)),\\
&n - 3\mathbf{K}(n) - (\mathbf{I}(\langle\tau\rangle : \mathcal{H}) + \mathbf{K}(p)\\
&\quad + O(\log(\mathbf{I}(\langle\tau\rangle{:}\mathcal{H}){+}\mathbf{K}(p)))) {<} \max_{a\in\tau(n)} \mathbf{d}(a|p). \square
\end{aligned}
$$

Let k be the physical address of τ. $\mathcal{H}$ can be described by a small mathematical statement. By Theorem 1 and IP,

$$
s_{\tau,p} <^{\log} \mathbf{I}(\langle\tau\rangle : \mathcal{H}) + \mathbf{K}(p) <^{\log} k + c + \mathbf{K}(p).
$$

So it's hard to find observations which do not have large anomalies and impossible to find observations with no anomalies.

References

[Eps21] Samuel Epstein. All sampling methods produce outliers. *IEEE Transactions on Information Theory*, 67(11):7568–7578, 2021.

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