

Notes on the paper “Short Labels by Traversal and Jumping”

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Abstract

This is a correction to the labeling scheme for Caterpillars, after the remarks raised by Martin Böhm¹. The new label length is 1 bit larger.

1 Labeling the Caterpillars

The scheme is essentially the same, mainly its analysis is changed. We use the same notations. The main difference is that the length p_i of the interval where $\ell(x_i)$ is computed is set to $p_i = 2^{t_i+4}$ instead of $p_i = 2^{t_i+3}$. For $C(x_i)$ we keep its initial definition, that is:

$$C(x_i) = \text{code}_0(t_i + 3 - |\text{code}_1(t_{i+1})|) \circ \text{code}_1(t_{i+1}) .$$

The adjacency scheme is the same. Here are the constraints that all t_i and p_i must fulfill:

1. $t_i + 3 - |\text{code}_1(t_{i+1})| \geq 0$ and $t_{i+1} \geq 0$, because of the definition of $C(x_i)$.
2. $p_i \geq 2^{|C(x_i)|}$ because $\ell(x_i)$ must encode $C(x_i)$ thanks to the coding Claim.
3. $p_i \geq d_i + 1$ because the interval $[\ell(x_i), \ell(x_i) + p_i)$ must be large enough to contain at least $\ell(x_i)$ and the labels of its d_i leaves attached to x_i .

Condition 2 is equivalent to $\lg p_i \geq |C(x_i)| = 1 + (t_i + 3 - |\text{code}_1(t_{i+1})|) + |\text{code}_1(t_{i+1})|$, that is true since precisely we have set $\lg p_i = t_i + 4$. Condition 3 is equivalent to $t_i + 4 \geq \lg(d_i + 1)$. All these conditions are fulfilled if we set:

$$t_i = \max \{0, |\text{code}_1(t_{i+1})| - 3, \lceil \lg d_i \rceil - 4\} , \text{ with } t_{k+1} = 0 .$$

Appart the extra bit added to the label to distinguish inner vertices and leaves, the maximum label assigned by the scheme above is no more than $2 \sum_{i=1}^k p_i$. The analysis of $\sum p_i$ is slightly simpler, although quite similar to the original one.

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Let us prove property (P_m) that is:

$$\sum_{i=m}^k p_i \leq \left(2^5 \sum_{i=m}^k \lceil d_i + 1 \rceil_2 \right) - p_m .$$

Recall that $\lceil x \rceil_2 = 2^{\lceil \lg x \rceil}$. Note that by definition of t_i , only three values are possible for p_i :

$$\begin{aligned} p_i = 2^{4+t_i} &= 2^{4+\max\{0, |\text{code}_1(t_{i+1})| - 3, \lceil \lg d_i \rceil - 4\}} \\ &= \max \{ 2^4, 2^{|\text{code}_1(t_{i+1})| + 1}, \lceil d_i + 1 \rceil_2 \} . \end{aligned}$$

For (P_k) , the left term is $A = p_k$ whereas the right term is $B = 2^5 \lceil d_k + 1 \rceil - p_k$. Thus $A \leq B$ iff $p_k \leq 2^4 \lceil d_k + 1 \rceil$.

(1) If $p_k = \lceil d_k + 1 \rceil$, then we are done.

(2) If $p_k = 2^4$, then we are done since $\lceil d_i + 1 \rceil \geq 1$ for all $d_i \geq 0$.

(3) If $p_k = 2^{|\text{code}_1(t_{k+1})| + 1}$. Note that $t_{k+1} = 0$ and that $|\text{code}_1(0)| = 2$. Thus $p_k = 2^3$, and we are done.

Therefore, (P_k) is proved. Assume that (P_i) is true for all indices $i \in \{m, \dots, k\}$ for some $m > 1$. Let us prove (P_{m-1}) .

The left term is now $A = \sum_{i=m-1}^k p_i$ which by assumption is

$$A = p_{m-1} + 2^5 \sum_{i=m}^k \lceil d_i + 1 \rceil_2 - p_m .$$

The right term is $B = 2^5 \sum_{i=m-1}^k \lceil d_i + 1 \rceil_2 - p_{m-1}$ which is also

$$B = 2^5 \lceil d_{m-1} + 1 \rceil_2 + 2^5 \sum_{i=m}^k \lceil d_i + 1 \rceil_2 - p_{m-1} .$$

Hence, $A \leq B$ iff $p_{m-1} - p_m \leq 2^5 \lceil d_{m-1} + 1 \rceil_2 - p_{m-1}$ that is also:

$$p_{m-1} \leq \frac{1}{2} p_m + 2^4 \lceil d_{m-1} + 1 \rceil_2 .$$

Let us prove the latter equation.

(1) If $p_{m-1} = \lceil d_{m-1} + 1 \rceil_2$ or 2^4 , then we are done.

(2) If $p_{m-1} = 2^{|\text{code}_1(t_m)| + 1}$. We observe that for every integer $x \geq 0$, $|\text{code}_1(x)| = 2|\text{bin}(x)|$. Moreover we check that $2|\text{bin}(x)| \leq x + 2$. The first values for $2|\text{bin}(x)|$ are 2, 2, 4, 4, 6, 6, 6, 6, 8, ... whereas for $x + 2$ there are: 2, 4, 6, 8, 10, ...

In particular, $2^{|\text{code}_1(t_m)| + 1} \leq 2^{t_m + 3} = \frac{1}{2} p_m$. It follows that $p_{m-1} \leq \frac{1}{2} p_m$, and we have proved that (P_m) is true.

Let $\ell(n)$ be the maximum label assigned by the scheme above. We have $\ell(n) \leq 2 \sum_{i=1}^k p_i \leq 2^6 \sum_{i=1}^k [d_i + 1]$. We observe that for all $x \geq 0$, $\lceil x + 1 \rceil_2 \leq \max \{2x, 1\}$. Thus,

$$\ell(n) \leq 2^6 \cdot \sum_{i=1}^k \max \{2d_i, 1\} = 2^6 \cdot \max \left\{ 2 \sum_{i=1}^k d_i, k \right\} = 2^6 \cdot \max \{2(n - k), k\}$$

since $\sum_{i=1}^k d_i = n - k$. If $k \geq 2n/3$, then $\max \{2(n - k), k\} = k \leq n$. if $k < 2n/3$, then $\max \{2(n - k), k\} = 2(n - k) < 2n/3$. It follows that $\ell(n) \leq 2^6 \cdot n$.

In conclusion, the label length is no more than $\lceil \log n \rceil + 6 + 1$ bits.