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Count(q) versus the Pigeon-Hole Principle

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Abstract

For each $p \leq 2$ there exist a model $\mathbb{M}^*$ of $I\Delta_0(\alpha)$ which satisfies the Count(p) principle. Furthermore if p contain all prime factors of q there exist $n, r \in \mathbb{M}^*$ and a bijective map $f \in \text{Set}(\mathbb{M}^*)$ mapping $\{1, 2, ..., n\}$ onto $\{1, 2, ..., n + q^r\}$.

A corollary is a complete classification of the Count(q) versus Count(p) problem. Another corollary solves an open question ([3]).

In this note I state and prove a Theorem which actually can be viewed as the main result of [9].

Theorem: *Suppose that $r(n)$ is an function with*

(a) $lim_{n\to\infty}\ r(n) = \infty$.

(b) *For all* $\epsilon > 0$ $lim_{n\to\infty} \frac{q^{r(n)}}{n^\epsilon} = 0$

For each $q, p \geq 2$ $\text{Count}(p) \not\vdash \text{PHP}^*_{*+q^{r(*)}}(\text{bij})$ *if p divides a power of q.*

Here $\text{PHP}^*_{*+s}(\text{bij})$ is the the elementary principle stating that *there does not exists n and a bijective map from* $\{1, 2, ..., n\}$ *onto* $\{1, 2, ..., n + s\}$.And Count(p) is the elementary matching principle stating that *if* $\{1, 2, ..., n\}$ *is divided into disjoint p-element subsets, then p divides n.*

Proof: As in [9] let $\mathbb{M}$ be a countable non-standard model of first order Arithmetic. Then by a similar forcing construction (which actually avoids

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certain technical problems) we expand $\mathbb{M}$ by a generic bijection f mapping $\{1, 2, ..., n\}$ onto $\{1, 2, ..., n + q^{r(n)}\}$. Assumption (a) allows us to assume that $q^{r(n)}$ is a non-standard number. Furthermore condition (b) ensures that the circuit collapsing argument goes through. Now it follows by the analysis in [9] that the Count(p) principle can never be forced false. If it was false, there would exists an impossible $\mathbb{M}$-definable object. In this case a forest of (D, R)-labelled trees where $\mid R \mid - \mid D \mid = q^{r(n)}$, but where all trees would have hight dominated by some standard number. This violates the main lemma (lemma 6.1.5) in [9]. Finally $\mathbb{M}^*$ is got a the initial segment $\{m \in \mathbb{M} : \ n^k > m, k \in \mathbb{N}\}$. □

Corollary 1: *Let $r(n)$ be as above. For each $q, p \geq 2$*
Count(p) $\not\vdash$ $\mathrm{PHP}^*_{*+q^{r(*)}}$(bij) *if and only if p divides a power of q.*

Corollary 2: *For fixed $q, p \geq 2$ the following is equivalent*

(a) *p divides a power of q*

(b) Count*(q)* $\vdash$ Count*(p).*

Proof: The implication (a) $\Rightarrow$ (b) was shown in [4] or [9]. The implication (b) $\Rightarrow$ (a) follows from the Theorem. According to the Theorem Count(p) $\not\vdash$ $\mathrm{PHP}^*_{*+q^{r(*)}}$(bij) if Count($q$) $\vdash$ Count(p). But then by the easy 'only if' in corollary 1, p must divide a power of q. □

Let PHP^{*+p}_{*}(inj) be the the statement that *there is no n and no injective map from* $\{1, 2, ..., n+p\}$ *into* $\{1, 2, ..., n\}$ and let PHP^*_{*+p}(sur) be the statement that *there is no n and no surjective map from* $\{1, 2, .., n\}$ *onto* $\{1, 2, ..., n+p\}$.

Corollary 3:

(a) PHP^*_{*+1}(bij) $\not\vdash$ PHP^{*+1}_{*}(inj).

(b) PHP^{*+1}_{*}(inj) $\dashv\vdash$ PHP^*_{*+1}(sur).

(c) Count*(q)* $\not\vdash$ PHP^{*+1}_{*}(inj).

Proof: (b) is a simple exercise, and (a) clearly follows from (c). To show (c) notice that PHP^{*+1}_{*}(inj) $\vdash$ $\mathrm{PHP}^*_{*+q^{r(*)}}$(bij) for any r. □
This solves an open question concerning the strength of the pigeon hole principle for injective maps [3]. Actually it shows that:

Corollary 4: *There exists a model $\mathbb{M}^*$ of $I\Delta_0(\alpha)$ in which* Count*(p) holds for each $p \in \mathbb{N} \setminus \{1\}$. Yet, there exists $n \in \mathbb{M}^*$ and an injective map $f \in \mathrm{Set}(\mathbb{M}^*)$ mapping $\{1, 2, ..., n + 1\}$ into $\{1, 2, ..., n\}$.*

Proof: By the completeness theorem it suffice to show that for each finite set $p_1, p_2, .., p_l$ of integers, the conjunction Count(p_1) $\wedge$ ....$\wedge$ Count(p_l) does not imply PHP_*^{*+1}(inj). This follows by an argument similar to the one given for (c) in corollary 3. $\square$

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