

My notes on "The Strong Factorial Conjecture" by Eric Edo and Arno van den Essen.
 See: <https://arxiv.org/abs/1304.3956>

1 Factorial Conjecture

$\mathbb{C}^{[m]}$ may be viewed as a vector space over \mathbb{C} with a basis being

$$\left\{ X_1^{l_1} \cdots X_m^{l_m} \mid l_k \in \mathbb{N}_0 \text{ for all } 1 \leq k \leq m \right\}.$$

Thus any linear map is fully defined if we set a value for each basis element. Such linear map is the factorial map.

Definition 1. We call the linear map $\mathcal{L} : \mathbb{C}^{[m]} \rightarrow \mathbb{C}$ defined by

$$\mathcal{L}(X_1^{l_1} \cdots X_m^{l_m}) = l_1! \cdots l_m! \quad \text{for all } l_1, \dots, l_m \in \mathbb{N}$$

Theorem 2 (Conjecture 2.4). Let $f \in \mathbb{C}^{[m]}$ be a polynomial. We have $\mathcal{L}(f^k) = 0$ for all $k \in \mathbb{N}_+$ if and only if $f = 0$.

2 Rigidity Conjecture

When we consider compositions of formal power series, we always want the constant term to be 0.

The following example is taken from:

<https://math.stackexchange.com/questions/1212053/defining-composition-of-two-formal-series-what-is-going-on>

Example 2.1. Let $f = \sum_{k \in \mathbb{N}_0} a_k X^k$ and $g = 1 + X$. Consider $f \circ g$. We have

$$\begin{aligned} f \circ g &= \sum_{k \in \mathbb{N}_0} a_k (1 + X)^k \\ &= a_0 + a_1 + a_1 X + a_2 + 2a_2 X + a_2 X^2 + \cdots \end{aligned}$$

If $f \circ g$ is again a formal power series, then we should be able to write $f \circ g = \sum_{k \in \mathbb{N}_+} c_k X^k$ for some $c_k \in \mathbb{C}$. However, we see that c_0 is the sum of all a_k and we cannot evaluate that as algebraists. Thus composition of formal power series only makes sense if the constant coefficient is 0.

Proposition 3. A power series $f(X) = \sum_{k \in \mathbb{N}_+} a_k X^k \in \mathbb{C}[[X]]$ has a compositional inverse $f^{-1}(X)$ if and only if $a_1 \neq 0$, in which case $f^{-1}(X)$ is unique.

Proof. Let $g(X) = b_1 X + b_2 X^2 + \cdots \in \mathbb{C}[[X]]$ be some power series that satisfies $f(g(X)) = X$. We have

$$X = a_1(b_0 + b_1 X + b_2 X^2 + \cdots) + a_2(b_0 + b_1 X + b_2 X^2 + \cdots)^2 + \cdots \quad (1)$$

$$= a_1 b_0 + a_2 b_0 + \cdots + \quad (2)$$

$$a_1 b_1 X \quad (3)$$

□

Theorem 4 (Conjecture 2.13). Let $a(X) \in \mathbb{C}[X]$ be a polynomial of degree less or equal to $m+1 \in \mathbb{N}_+$ such that $a(X) \equiv X \pmod{X^2}$. If the first m consecutive coefficient of the compositional inverse $a^{-1}(X)$ vanish, then $a(X) = X$.

Theorem 5 (Conjecture 2.14). Let $a(X) \in \mathbb{C}[X]$ be a polynomial of degree less or equal to $m+1 \in \mathbb{N}_+$ such that $a(X) \equiv X \pmod{X^2}$. If the coefficients of X^{n+1}, \dots, X^{n+m} of the compositional inverse vanish, then $a(X) = X$.

Remark. $R(m)$ if and only if $R(m)_n$ for all $n \in \mathbb{N}_+$.

Proof. Let $R(m)$ be true for a $m \in \mathbb{N}_0$.

Then $R(m)_1$ is true, i.e. if $\deg(a) \leq m + 1$ and if the

□

Remark. If we denote the polynomial $a(X)$ by $\sum_{k \in \mathbb{N}_0} a_k X^k$ for some $a_k \in \mathbb{C}$ for all $k \in \mathbb{N}_0$, then the condition $a(X) \equiv X \pmod{X^2}$ amounts to $a_0 = 0$ and $a_1 = 1$.

Moreover, we have this:

A power series has a compositional inverse if and only if $a_1 \neq 0$. In that case, the inverse is unique.

See

<https://www.amazon.com/dp/B00HMUGS4S>

<https://math.stackexchange.com/questions/2520744/finding-compositional-inverses-for-formal-power-series>

My questions:

1. What if $a_0 \neq 0$? Pick $a_0 = 3$.

Let $f \in \mathbb{C}[X]$ be a polynomial with $a_0 \neq 0$. Then we may write $f(X) = g(X) + a_0$ where g has a compositional inverse. Thus it

$$\begin{aligned} g^{-1}(g(X) + a_0) &= g^{-1}(g(X)) + g^{-1}(a_0) \\ &= X + g^{-1}(a_0) \end{aligned}$$

$$\begin{aligned} h(X) &= g^{-1}(X) + g^{-1}(a_0) \\ h(f(X)) &= h(g(X) + a_0) \\ &= g^{-1}(g(X) + a_0) + g^{-1}(a_0) \\ &= X \end{aligned}$$

Let $f \in \mathbb{C}[X]$ be a polynomial with $a_1 \neq 1$ and $a_1 \neq 0$. Then we may write $f(X) =$

<https://www.math.uwaterloo.ca/~dgwagner/co430I.pdf>

proof

Proposition 6. 1. The polynomial $a(X)$ is invertible for the composition.

2. For all $i \in \{1, \dots, \deg(a) - 1\}$, the coefficient a_i is nilpotent element in A . I just don't see this ...

Lemma 7 (Lagrange Inversion Formula). Let K be a field of characteristic

Example 7.1 (See 5.4.4). $f(X) = Xe^{-X} = X \sum_{k=0}^{\infty} \frac{(-1)^k}{k!} X^k$

$$[X^n]f^{-1}(X) = \frac{1}{n} [X^{n-1}]e^{nX}$$

Lemma 8 (Lemma 2.20 (Additive Inversion Formula)). Let $\alpha_1, \dots, \alpha_m \in \mathbb{C}$ be complex numbers. The formal inverse of $a(X) = X(1 - (\alpha_1 X + \dots + \alpha_m X^m))$ is given by the following formula

$$a^{-1}(X) = X \left(1 + \frac{1}{n+1} \sum_{n \geq 1} u_n X^n \right)$$

where

$$u_n = \frac{1}{n!} \sum_{j_1 + 2j_2 + \dots + mj_m = n} \frac{(n + j_1 + \dots + j_m)!}{j_1! \dots j_m!} \alpha_1^{j_1} \dots \alpha_m^{j_m}$$

Proposition 9 (Proposition 2.23). Let $\alpha_1, \dots, \alpha_m \in \mathbb{C}$ be complex numbers and let $(u_n)_{n \in \mathbb{N}_+}$ be a sequence defined by AIF in Lemma 2.20. For all $n \in \mathbb{N}_+$, the Rigidity Conjecture $R(m)_n$ is equivalent to the following implication: If $u_n = \dots = u_{n+m-1} = 0$ then $\alpha_1 = \dots = \alpha_m = 0$.

Proof.

□

Theorem 10. 1. The inclusion $E^{[m]} \subset F_n^{[m]}$ implies $R(m)_n$

Definition 11.

$$E^{[m]} = \{ X_1 \cdots X_m (\mu_1 X_1 + \cdots + \mu_m X_m) \mid \mu_1, \dots, \mu_m \in \mathbb{C} \} \subset$$

$$F_n^{[m]} = \left\{ f \in \mathbb{C}^{[m]} \setminus \{0\} \mid \mathcal{L}(f^k) \neq 0 \text{ for some } n \leq k \leq \mathcal{N}(f) - 1 \right\} \cup \{0\}$$