广义 Fibonacci 数列一些前 n 项和式初等证明*

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摘 要:用数学初等方法证明了广义 Fibonacci 数列的相差小于6的前 n 项的和式,从而就能得到 Fibonacci 数列、Lucas 数列的相差小于6的前 n 项的和式,通过这些数列的通项就能轻松计算其值。

关键词:Fibonacci 数列;Lucas 数列;广义 Fibonacci 数列;前 n 项和式
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Fibonacci 数列是一个有悠久历史的数列,在很多领域都得到应用,特别是在否证 Hilbert 第十问题时显现了它的强大威力。Fibonacci 数列、Lucas 数列的研究论文和著作也十分丰富。文献[1]和[2]中讨论了广义 Fibonacci 数列,用数学归纳法证明了它的相差1-7的前 n 项的和式,但是他们都是应用数学归纳法证明。本文用初等方法证明了它的相差小于6的前 n 项的和式。

广义 Fibonacci 数列 $\{h_n\}$ 可以用递推公式表示如下[3]:

$$\begin{cases} h_1 = a, h_2 = b, (a,b \in Z; ab \neq 0) \\ h_{n+2} = h_{n+1} + h_n, (n \geq 1) \end{cases}$$

当 $a=1, b=1$ 时,$\{h_n\}$ 就是 Fibonacci 数列,记为 $\{f_n\}$;当 $a=1, b=3$ 时,$\{h_n\}$ 就是 Lucas 数列,记为 $\{l_n\}$。特别令 $h_0 = h_2 - h_1 = (b-a)$,

定理1 $\sum_{i=1}^{n} h_i = h_{n+2} - b$

证明: $\sum_{i=1}^{n} h_i = h_1 + h_2 + h_3 + \cdots + h_n =$

$$-h_2 + h_2 + h_1 + h_2 + h_3 + \cdots + h_n =$$
$$-h_2 + h_3 + h_2 + h_3 + \cdots + h_n =$$
$$-h_2 + h_4 + h_3 + \cdots + h_n = -h_2 + h_5 + \cdots + h_n =$$
$$-h_2 + h_{n+1} + h_n = h_{n+2} - h_2 = h_{n+2} - b.$$

推论1 令 $a=1, b=1$,数列 $\{h_n\}$ 是 Fibonacci 数列 $\{f_n\}$。则[4] $\sum_{i=1}^{n} f_i = f_{n+2} - 1$;

令 $a=1, b=3$,数列 $\{h_n\}$ 是 Lucas 数列 $\{l_n\}$。则[5] $\sum_{i=1}^{n} l_i = l_{n+2} - 3$.

定理2 $\sum_{i=1}^{n} h_{2i-1} = h_{2n} + a - b$.

证明: $\sum_{i=1}^{n} h_{2i-1} = h_1 + h_3 + \cdots + h_{2n-1} =$

$$h_1 + (h_1 + h_2) + (h_3 + h_4) + \cdots + (h_{2n-3} + h_{2n-2}) =$$
$$\sum_{j=1}^{2n-2} h_j + h_1 = h_{2n} - b + a$$

定理3 $\sum_{i=1}^{n} h_{2i} = h_{2n+1} - a$

证明: $\sum_{i=1}^{n} h_2 + h_4 + \cdots + h_{2n} = h_2 - h_1 + h_1 +$

$$(h_2 + h_3) + \cdots + (h_{2n-2} + h_{2n-1}) =$$
$$\sum_{j=1}^{2n-1} h_j + h_2 - h_1 = h_{2n+1} - a$$

推论2 令 $a=1, b=1$,数列 $\{h_n\}$ 是 Fibonacci 数列 $\{f_n\}$。则[4]

$$\sum_{i=1}^{n} f_{2i-1} = f_{2n}; \quad \sum_{i=1}^{n} f_{2i} = f_{2n+1} - 1$$

令 $a=1, b=3$,数列 $\{h_n\}$ 是 Lucas 数列 $\{l_n\}$。则[1]

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$$\sum_{i=1}^{n} l_{2i-1} = l_{2n} - 2; \quad \sum_{i=1}^{n} l_{2}i = l_{2n+1} - 1$$

定理 4　$$\sum_{i=1}^{n} h_{3i} = \frac{1}{2}(h_{3n+2} - b)$$

证明:　$2\sum_{i=1}^{n} h_{3i} = 2h_3 + 2h_6 + \cdots + 2h_{3n} =$

$$(h_1 + h_2) + h_3 + (h_4 + h_5) + h_6 + \cdots + (h_{3n-2} + h_{3n-1}) + h_{3n} = \sum_{j=1}^{3n} h_j = h_{3n+2} - b$$

定理 5　$$\sum_{i=1}^{n} h_{3i-1} = \frac{1}{2}(h_{3n+1} - a)$$

证明:

$$2\sum_{i=1}^{n} h_{3i-1} = 2h_2 + 2h_5 + \cdots + 2h_{3n-1} =$$

$$(h_2 - h_1 + h_1) + h_2 + (h_3 + h_4) + h_5 + \cdots + (h_{3n-3} + h_{3n-2}) + h_{3n-1} = \sum_{j=1}^{3n-1} h_j + h_2 - h_1 =$$

$$h_{3n+1} - b + b - a$$

定理 6　$$\sum_{i=1}^{n} h_{3i-2} = \frac{1}{2}(h_{3n} - b + a)$$

证明:　$2\sum_{i=1}^{n} h_{3i-2} = 2h_1 + 2h_4 + \cdots + 2h_{3n-2} =$

$$\sum_{j=1}^{3n-2} h_j + h_1 = h_{3n} - b + a$$

推论 3　令 $a = 1, b = 1$,数列 $\{h_n\}$ 是 Fibonacci 数列 $\{f_n\}$。则

$$\sum_{i=1}^{n} f_{3i} = \frac{1}{2}(f_{3n+2} - 1)^{[2]};$$

$$\sum_{i=1}^{n} f_{3i-1} = \frac{1}{2}(f_{3n+1} - 1);$$

$$\sum_{i=1}^{n} f_{3i-2} = \frac{1}{2}f_{3n}$$

令 $a = 1, b = 3$,数列 $\{h_n\}$ 是 Lucas 数列 $\{l_n\}$。

则　$$\sum_{i=1}^{n} l_{3i} = \frac{1}{2}(l_{3n+2} - 3);$$

$$\sum_{i=1}^{n} l_{3i-1} = \frac{1}{2}(l_{3n+1} - 1);$$

$$\sum_{i=1}^{n} l_{3i} = \frac{1}{2}(l_{3n} - 2)$$

定理 7

$$\sum_{i=1}^{n} h_{4i} = \frac{1}{5}(3h_{4n+1} + h_{4n} - b - 2a)$$

$$\sum_{i=1}^{n} h_{4i-1} = \frac{1}{5}(h_{4n+1} + 2h_{4n} - 2b + a)$$

$$\sum_{i=1}^{n} h_{4i-2} = \frac{1}{5}(2h_{4n+1} - h_{4n} + b - 3a)$$

$$\sum_{i=1}^{n} h_{4i-3} = \frac{1}{5}(-h_{4n+1} + 3h_{4n} - 3b + 4a)$$

证明:　$$\sum_{i=1}^{n} h_{4i-2} + \sum_{i=1}^{n} h_{4i} = \sum_{i=1}^{2n} h_{2j} \quad \cdots\cdots \quad (1)$$

$$3\sum_{i=1}^{n} h_{4i} = \sum_{i=1}^{n}(2h_{4i-2} + 2h_{4i-1} + h_{4i}) =$$

$$\sum_{i=1}^{n}(h_{4i-3} + 3h_{4i-2} + h_{4i-1} + h_{4i}) =$$

$$\sum_{i=1}^{n}(h_{4i-3} + h_{4i-2} + h_{4i} + h_{4i}) + \sum_{i=1}^{n} 2h_{4i-2} =$$

$$\sum_{j=1}^{4n} h_j + 2\sum_{i=1}^{n} h_{4i-2} \cdots\cdots \quad (2)$$

由上两式:$5\sum_{i=1}^{n} h_{4i} = \sum_{j=1}^{4n} h_j + 2\sum_{j=1}^{2n} h_{2j} =$

$$(h_{4n+2} - b) + 2(h_{4n+1} - a) = 3h_{4n+1} + h_{4n} - b - 2a$$

所以由(1)式:

$$\sum_{i=1}^{n} h_{4i-2} = \sum_{j=1}^{2n} h_{2j} - \sum_{i=1}^{n} h_{4i} =$$

$$(h_{4n+1} - a) - \frac{1}{5}(3h_{4n+1} + h_{4n} - b - 2a) =$$

$$\frac{1}{5}(2h_{4n+1} - h_{4n} + b - 3a)$$

由数列 $\{h_n\}$ 的递推性质得:

$$\sum_{i=1}^{n} h_{4i-1} = \sum_{i=1}^{n} h_{4i} - \sum_{i=1}^{n} h_{4i-2} = \frac{1}{5}(3h_{4n+1} + h_{4n} - b - 2a) - \frac{1}{5}(2h_{4n+1} - h_{4n} + b - 3a) =$$

$$\frac{1}{5}(h_{4n+1} + 2h_{4n} - 2b + a)$$

$$\sum_{i=1}^{n} h_{4i-3} = \sum_{i=1}^{n} h_{4i} - \sum_{i=1}^{n} h_{4i-2} = \frac{1}{5}(h_{4n+1} + 2h_{4n} - 2b + a) - \frac{1}{5}(2h_{4n+1} - h_{4n} + b - 3a) =$$

$$\frac{1}{5}(-h_{4n+1} + 3h_{4n} - 3b + 4a)$$

推论 4　令 $a = 1, b = 1$,数列 $\{h_n\}$ 是 Fibonacci 数列 $\{f_n\}$。则

$$\sum_{i=1}^{n} f_{4i} = \frac{1}{5}(3f_{4n+1} + f_{4n} - 3)^{[4]};$$

$$\sum_{i=1}^{n} f_{4i-1} = \frac{1}{5}(f_{4n+1} + 2f_{4n} - 1)$$

$$\sum_{i=1}^{n} f_{4i-2} = \frac{1}{5}(2f_{4n+1} - f_{4n} - 2);$$

$$\sum_{i=1}^{n} f_{4i-3} = \frac{1}{5}(-f_{4n+1} + 3f_{4n} + 1)$$

令 $a = 1, b = 3$,数列 $\{h_n\}$ 是 Lucas 数列 $\{l_n\}$。

则

$$\sum_{i=1}^{n} l_{4i} = \frac{1}{5}(3l_{4n+1} + l_{4n} - 5)^{[4]};$$

$$\sum_{i=1}^{n} l_{4i-1} = \frac{1}{5}(l_{4n+1} + 2l_{4n} - 5)$$

$$\sum_{i=1}^{n} l_{4i-2} = \frac{1}{5}(2l_{4n+1} - l_{4n});$$

$$\sum_{i=1}^{n} l_{4i-3} = \frac{1}{5}(-l_{4n+1} + 3l_{4n} - 5)$$

定理8: $\sum_{i=1}^{n} h_{5i} = \frac{1}{11}(4h_{5n+2} + h_{5n+1} - a - 4b)$

$$\sum_{i=1}^{n} h_{5i-1} = \frac{1}{11}(h_{5n+2} + 3h_{5n+1} - 3a - b)$$

$$\sum_{i=1}^{n} h_{5i-2} = \frac{1}{11}(3h_{5n+2} - 2h_{5n+1} + 2a - 3b)$$

$$\sum_{i=1}^{n} h_{5i-3} = \frac{1}{11}(-2h_{5n+2} + 5h_{5n+1} - 5a + 2b)$$

$$\sum_{i=1}^{n} h_{5i-4} = \frac{1}{11}(5h_{5n+2} - 7h_{5n+1} + 7a - 5b)$$

证明: $3\sum_{i=1}^{n} h_{5i} = \sum_{i=1}^{n}(2h_{5i} + h_{5i-1} + h_{5i-2}) =$

$\sum_{i=1}^{n}(h_{5i} + h_{5i-1} + h_{5i-2} + h_{5i-3} + h_{5i-4} +$

$h_{5i-1}) = \sum_{j=1}^{5n} h_j + \sum_{i=1}^{n} h_{5i-1} \quad \cdots \qquad (1)$

$3\sum_{i=1}^{n} h_{5i-1} = \sum_{i=1}^{n}(2h_{5i-1} + h_{5i-2} + h_{5i-3}) =$

$\sum_{i=1}^{n}(h_{5i-1} + h_{5i-2} + h_{5i-3} + h_{5i-4} + h_{5i-5} +$

$h_{5i-2}) = \sum_{j=1}^{5n-1} h_j + \sum_{i=1}^{n} h_{5i-2} + h_0 \quad \cdots \qquad (2)$

由(1)式得:

$$3\sum_{i=1}^{n} h_{5i-1} + 3\sum_{i=1}^{n} h_{5i-2} = \sum_{j=1}^{5n} h_j + \sum_{i=1}^{n} h_{5i-1}$$

$$2\sum_{i=1}^{n} h_{5i-1} + 3\sum_{i=1}^{n} h_{5i-2} = \sum_{j=1}^{5n} h_j = h_{5n+2} - b$$

$\cdots\cdots \qquad (3)$

由(2)式得: $3\sum_{i=1}^{n} h_{5i-1} - \sum_{i=1}^{n} h_{5i-2} = \sum_{j=1}^{5n-1} h_j + h_0 =$

$h_{5n+1} - b + (b - a) = h_{5n+1} - a \quad \cdots\cdots \qquad (4)$

由(3)、(4)式得:

$$11\sum_{i=1}^{n} h_{5i-1} = (h_{5n+2} - b + 3(h_{5n+1} - a)$$

$$11\sum_{i=1}^{n} h_{5i-2} = 3(h_{5n+2} - b) - 2(h_{5n+1} - a)$$

$$\sum_{i=1}^{n} h_{5i-1} = \frac{1}{11}(h_{5n+2} + 3h_{5n+1} - 3a - b)$$

$$\sum_{i=1}^{n} h_{5i-2} = \frac{1}{11}(3h_{5n+2} - 2h_{5n+1} + 2a - 3b)$$

$\sum_{i=1}^{n} h_{5i} = \sum_{i=1}^{n} h_{5i-1} + \sum_{i=1}^{n} h_{5i-2} =$

$\frac{1}{11}(4h_{5n+2} + h_{5n+1} - a - 4b)$

$\sum_{i=1}^{n} h_{5i-3} = \sum_{i=1}^{n} h_{5i-1} - \sum_{i=1}^{n} h_{5i-2} =$

$\frac{1}{11}(-2h_{5n+2} + 5h_{5n+1} - 5a + 2b)$

$\sum_{i=1}^{n} h_{5i-4} = \sum_{i=1}^{n} h_{5i-2} - \sum_{i=1}^{n} h_{5i-3} =$

$\frac{1}{11}(5h_{5n+2} - 7h_{5n+1} + 7a - 5b)$

推论5 令 $a=1, b=1$,数列$\{h_n\}$是 Fibonacci 数列$\{f_n\}$。则

$$\sum_{i=1}^{n} f_{5i} = \frac{1}{11}(4f_{5n+2} + f_{5n+1} - 5)^{[4]}$$

$$\sum_{i=1}^{n} f_{5i-1} = \frac{1}{11}(f_{5n+2} + 3f_{5n+1} - 4)$$

$$\sum_{i=1}^{n} f_{5i-2} = \frac{1}{11}(3f_{5n+2} - 2f_{5n+1} - 1)$$

$$\sum_{i=1}^{n} f_{5i-3} = \frac{1}{11}(-2f_{5n+2} + 5f_{5n+1} - 3)$$

$$\sum_{i=1}^{n} f_{5i-4} = \frac{1}{11}(5f_{5n+2} - 7f_{5n+1} + 2)$$

令 $a=1, b=3$,数列$\{h_n\}$是 Lucas 数列$\{l_n\}$。则

$$\sum_{i=1}^{n} l_{5i} = \frac{1}{11}(4l_{5n+2} + l_{5n+1} - 13)$$

$$\sum_{i=1}^{n} l_{5i-1} = \frac{1}{11}(l_{5n+2} + 3l_{5n+1} - 6)$$

$$\sum_{i=1}^{n} l_{5i-2} = \frac{1}{11}(3l_{5n+2} - 2l_{5n+1} - 7)$$

$$\sum_{i=1}^{n} l_{5i-3} = \frac{1}{11}(-2l_{5n+2} + 5l_{5n+1} + 1)$$

$$\sum_{i=1}^{n} l_{5i-4} = \frac{1}{11}(5l_{5n+2} - 7l_{5n+1} - 8)$$

定理9 $\sum_{i=1}^{n} h_{6i} = \frac{1}{4}(h_{6n+3} - a - b)$

$$\sum_{i=1}^{n} h_{6i-1} = \frac{1}{4}(h_{6n+2} - b)$$

$$\sum_{i=1}^{n} h_{6i-2} = \frac{1}{4}(h_{6n+1} - a)$$

$$\sum_{i=1}^{n} h_{6i-3} = \frac{1}{4}(h_{6n+3} + a - b);$$

$$\sum_{i=1}^{n} h_{6i-4} = \frac{1}{4}(h_{6n-1} - 2a + b)$$

$$\sum_{i=1}^{n} h_{6i-5} = \frac{1}{4}(h_{6n-2} + 3a - 2b)$$

证明: $\sum_{i=1}^{n} h_{6i} + \sum_{i=1}^{n} h_{6i-2} + \sum_{i=1}^{n} h_{6i-4} = \sum_{j=1}^{3n} h_{2j} \cdots$ (1)

$$3\sum_{i=1}^{n} h_{6i} = \sum_{i=1}^{n}(2h_{6i} + h_{6i-1} + h_{6i-2}) = \sum_{i=1}^{n}(h_{6i} + h_{6i} + h_{6i-2} + 2h_{6i-3} + h_{6i-4}) = \sum_{i=1}^{n}(h_{6i} + h_{6i-1} + h_{6i-2} + h_{6i-3} + h_{6i-4} + h_{6i-5}) + \sum_{i=1}^{n}(h_{6i-2} + h_{6i-4}) = \sum_{j=1}^{6n} h_j + \sum_{i=1}^{n}(h_{6i-2} + h_{6i-4})$$

…… (2)

由(1)、(2)式得: $4\sum_{i=1}^{n} h_{6i} = \sum_{j=1}^{6n} h_j + \sum_{j=1}^{3n} h_{2j} = (h_{6n+2} - b) + (h_{6n+1} - a) = h_{6n+3} - a - b$

…… (3)

所以由(3)式和定理4:

$$\sum_{i=1}^{n} h_{6i-3} = \sum_{j=1}^{2n} h_{3j} - \sum_{i=1}^{n} h_{6i} = \frac{1}{2}(h_{6n+2} - b) - \frac{1}{4}(h_{6n+3} - a - b) = \frac{1}{4}(h_{6n} + a - b)$$

由数列$\{h_n\}$的递推性质得:

$$\sum_{i=1}^{n} h_{6i-2} - \sum_{i=1}^{n} h_{6i-4} = \sum_{i=1}^{n} h_{6i-3} \quad \cdots \quad (4)$$

由(1)式得:

$$\sum_{i=1}^{n} h_{6i-2} + \sum_{i=1}^{n} h_{6i-4} = \sum_{j=1}^{3n} h_{2j} - \sum_{i=1}^{n} h_{6i} \quad \cdots \quad (5)$$

由(4)、(5)式得:

$$\sum_{i=1}^{n} h_{6i-2} = \frac{1}{2}\left(\sum_{j=1}^{3n} h_{2j} - \sum_{i=1}^{n} h_{6i} + \sum_{i=1}^{n} h_{6i-3}\right) = \frac{1}{2}\left[(h_{6n+1} - a) - \frac{1}{4}(h_{6n+3} - a - b) + \frac{1}{4}(h_{6n} + a - b)\right] = \frac{1}{8}(4h_{6n+1} - 4a - h_{6n+3} + a + b + h_{6n} + a - b) = \frac{1}{4}(h_{6n+1} - a)$$

$$\sum_{i=1}^{n} h_{6i-4} = \frac{1}{2}\left(\sum_{j=1}^{3n} h_{2j} - \sum_{i=1}^{n} h_{6i} - \sum_{i=1}^{n} h_{6i-3}\right) = \frac{1}{2}\left[(h_{6n+1} - a) - \frac{1}{4}(h_{6n+3} - a - b) - \frac{1}{4}(h_{6n} + a - b)\right] = \frac{1}{8}(4h_{6n+1} - 4a - h_{6n+3} + a + b - h_{6n} - a + b) = \frac{1}{4}(h_{6n-1} - 2a + b)$$

$$\sum_{i=1}^{n} h_{6i-1} = \sum_{i=1}^{n} h_{6i} - \sum_{i=1}^{n} h_{6i-2} = \frac{1}{4}(h_{6n+3} - a - b) - \frac{1}{4}(h_{6n+1} - a) = \frac{1}{4}(h_{6n+2} - b)$$

$$\sum_{i=1}^{n} h_{6i-5} = \sum_{i=1}^{n} h_{6i-3} - \sum_{i=1}^{n} h_{6i-4} = \frac{1}{2}(h_{6n} + a - b) - \frac{1}{4}(h_{6n-1} - 2a + b) = \frac{1}{4}(h_{6n-2} + 3a - 2b)$$

推论6　令 $a=1, b=1$,数列$\{h_n\}$是 Fibonacci 数列$\{f_n\}$。则

$$\sum_{i=1}^{n} f_{6i} = \frac{1}{4}(f_{6n+3} - 2)$$

$$\sum_{i=1}^{n} f_{6i-1} = \frac{1}{4}(f_{6n+2} - 1)$$

$$\sum_{i=1}^{n} f_{6i-2} = \frac{1}{4}(f_{6n+1} - 1)$$

$$\sum_{i=1}^{n} f_{6i-3} = \frac{1}{4}f_{6n};$$

$$\sum_{i=1}^{n} f_{6i-4} = \frac{1}{4}(f_{6n-1} - 1)$$

$$\sum_{i=1}^{n} f_{6i-5} = \frac{1}{4}(f_{6n-2} + 1)$$

令 $a=1, b=3$,数列$\{h_n\}$是 Lucas 数列$\{l_n\}$。则

$$\sum_{i=1}^{n} l_{6i} = \frac{1}{4}(l_{6n+3} - 4)$$

$$\sum_{i=1}^{n} l_{6i-1} = \frac{1}{4}(l_{6n+2} - 3)$$

$$\sum_{i=1}^{n} l_{6i-2} = \frac{1}{4}(l_{6n+1} - 1)$$

$$\sum_{i=1}^{n} l_{6i-3} = \frac{1}{4}(l_{6n} - 2);$$

$$\sum_{i=1}^{n} l_{6i-4} = \frac{1}{4}(l_{6n-1} + 1)$$

$$\sum_{i=1}^{n} l_{6i-5} = \frac{1}{4}(l_{6n-2} - 3)$$

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Some Formals of Sum about General Fibonacci Sequence

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Abstract: The article has demonstrated an elementary proof about the sum of the first n item difference less than 6 of the generalized Fibonacci sequence. Thus, the sum of the first n item difference less than 6 of Fibonacci sequence, Lucas sequence could be obtained and its numerical value could be calculated by the general formals of these sequences.

Keywords: Fibonacci sequence; Lucas sequence; Generalized Fibonacci Sequence; the sum of the first n item

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Study on a Naw Algorithm of Feature Matching - SIFT

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Abstract: A new algorithm of feature matching - SIFT (Scale Invariant Feature Transform) which has become a hot topic and difficult research area is introduced. At present the algorithm, whose matching ability is more strong and can dispose of matching problem with translation, rotation and affine distortion between images and to a certain extent is with more stable feature matching ability for images which are shot from random different angles. The experiments show that the algorithm is of stronger matching ability and robustness, which is a better feature matching algorithm.

Keywords: virtual reality; feature matching; image mosaicing; panorama