Fibonacci Series C

Fibonacci sequence

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In mathematics, the Fibonacci sequence is a sequence in which each element is the sum of the two elements that precede it. Numbers that are part of the Fibonacci sequence are known as Fibonacci numbers, commonly denoted Fn . Many writers begin the sequence with 0 and 1, although some authors start it from 1 and 1 and some (as did Fibonacci) from 1 and 2. Starting from 0 and 1, the sequence begins

0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ... (sequence A000045 in the OEIS)

The Fibonacci numbers were first described in Indian mathematics as early as 200 BC in work by Pingala on enumerating possible patterns of Sanskrit poetry formed from syllables of two lengths. They are named after the Italian mathematician Leonardo of Pisa, also known as Fibonacci, who introduced the sequence to Western European mathematics in his 1202 book Liber Abaci.

Fibonacci numbers appear unexpectedly often in mathematics, so much so that there is an entire journal dedicated to their study, the Fibonacci Quarterly. Applications of Fibonacci numbers include computer algorithms such as the Fibonacci search technique and the Fibonacci heap data structure, and graphs called Fibonacci cubes used for interconnecting parallel and distributed systems. They also appear in biological settings, such as branching in trees, the arrangement of leaves on a stem, the fruit sprouts of a pineapple, the flowering of an artichoke, and the arrangement of a pine cone's bracts, though they do not occur in all species.

Fibonacci numbers are also strongly related to the golden ratio: Binet's formula expresses the n-th Fibonacci number in terms of n and the golden ratio, and implies that the ratio of two consecutive Fibonacci numbers tends to the golden ratio as n increases. Fibonacci numbers are also closely related to Lucas numbers, which obey the same recurrence relation and with the Fibonacci numbers form a complementary pair of Lucas sequences.

Fibonacci heap

In computer science, a Fibonacci heap is a data structure for priority queue operations, consisting of a collection of heap-ordered trees. It has a better

In computer science, a Fibonacci heap is a data structure for priority queue operations, consisting of a collection of heap-ordered trees. It has a better amortized running time than many other priority queue data structures including the binary heap and binomial heap. Michael L. Fredman and Robert E. Tarjan developed Fibonacci heaps in 1984 and published them in a scientific journal in 1987. Fibonacci heaps are named after the Fibonacci numbers, which are used in their running time analysis.

The amortized times of all operations on Fibonacci heaps is constant, except delete-min. Deleting an element (most often used in the special case of deleting the minimum element) works in

O

(

log

?

n

)

{\displaystyle O(\log n)}

amortized time, where

n

{\displaystyle n}

is the size of the heap. This means that starting from an empty data structure, any sequence of a insert and decrease-key operations and b delete-min operations would take

O

(

a

+

b

log

?

n

)

{\displaystyle O(a+b\log n)}

worst case time, where

n

{\displaystyle n}

is the maximum heap size. In a binary or binomial heap, such a sequence of operations would take

O

(

(

a

+

b

)

log

?

n

)

{\displaystyle O((a+b)\log n)}

time. A Fibonacci heap is thus better than a binary or binomial heap when

b

{\displaystyle b}

is smaller than

a

{\displaystyle a}

by a non-constant factor. It is also possible to merge two Fibonacci heaps in constant amortized time, improving on the logarithmic merge time of a binomial heap, and improving on binary heaps which cannot handle merges efficiently.

Using Fibonacci heaps improves the asymptotic running time of algorithms which utilize priority queues. For example, Dijkstra's algorithm and Prim's algorithm can be made to run in

O

(

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E

|

+

|

V

|

log

?

|

V

|

)

{\displaystyle O(|E|+|V|\log |V|)}

time.

Fibonacci

Leonardo Bonacci (c. 1170 – c. 1240–50), commonly known as Fibonacci, was an Italian mathematician from the Republic of Pisa, considered to be "the most

Leonardo Bonacci (c. 1170 – c. 1240–50), commonly known as Fibonacci, was an Italian mathematician from the Republic of Pisa, considered to be "the most talented Western mathematician of the Middle Ages".

The name he is commonly called, Fibonacci, is first found in a modern source in a 1838 text by the Franco-Italian mathematician Guglielmo Libri and is short for filius Bonacci ('son of Bonacci'). However, even as early as 1506, Perizolo, a notary of the Holy Roman Empire, mentions him as "Lionardo Fibonacci".

Fibonacci popularized the Indo–Arabic numeral system in the Western world primarily through his composition in 1202 of Liber Abaci (Book of Calculation) and also introduced Europe to the sequence of Fibonacci numbers, which he used as an example in Liber Abaci.

Fibonacci cube

In the mathematical field of graph theory, the Fibonacci cubes or Fibonacci networks are a family of undirected graphs with rich recursive properties derived

In the mathematical field of graph theory, the Fibonacci cubes or Fibonacci networks are a family of undirected graphs with rich recursive properties derived from its origin in number theory. Mathematically they are similar to the hypercube graphs, but with a Fibonacci number of vertices. Fibonacci cubes were first explicitly defined in Hsu (1993) in the context of interconnection topologies for connecting parallel or distributed systems. They have also been applied in chemical graph theory.

The Fibonacci cube may be defined in terms of Fibonacci codes and Hamming distance, independent sets of vertices in path graphs, or via distributive lattices.

Fibonacci coding

In mathematics and computing, Fibonacci coding is a universal code which encodes positive integers into binary code words. It is one example of representations

In mathematics and computing, Fibonacci coding is a universal code which encodes positive integers into binary code words. It is one example of representations of integers based on Fibonacci numbers. Each code word ends with "11" and contains no other instances of "11" before the end.

The Fibonacci code is closely related to the Zeckendorf representation, a positional numeral system that uses Zeckendorf's theorem and has the property that no number has a representation with consecutive 1s. The Fibonacci code word for a particular integer is exactly the integer's Zeckendorf representation with the order of its digits reversed and an additional "1" appended to the end.

Reciprocal Fibonacci constant

The reciprocal Fibonacci constant ? is the sum of the reciprocals of the Fibonacci numbers: ? = ? k = 1 ? 1 F k = 1 1 + 1 1 + 1 2 + 1 3 + 1 5 + 1 8 +

The reciprocal Fibonacci constant ? is the sum of the reciprocals of the Fibonacci numbers:

?

=

?

k

=

1

?

1

F

k

=

1

1

+

1

1

+

1

2

+

1

3

+

1

5

+

1

8

+

1

13

+

1

21

+

?

.

{\displaystyle \psi =\sum _{k=1}^{\infty }{\frac {1}{F_{k}}}={\frac {1}{1}}+{\frac {1}{1}}+{\frac {1}{2}}+{\frac {1}{3}}+{\frac {1}{5}}+{\frac {1}{8}}+{\frac {1}{13}}+{\frac {1}{21}}+\cdots .}

Because the ratio of successive terms tends to the reciprocal of the golden ratio, which is less than 1, the ratio test shows that the sum converges.

The value of ? is approximately

?

=

3.359885666243177553172011302918927179688905133732

…

{\displaystyle \psi =3.359885666243177553172011302918927179688905133732\dots }

(sequence A079586 in the OEIS).

With k terms, the series gives O(k) digits of accuracy. Bill Gosper derived an accelerated series which provides O(k 2) digits.

? is irrational, as was conjectured by Paul Erd?s, Ronald Graham, and Leonard Carlitz, and proved in 1989 by Richard André-Jeannin.

Its simple continued fraction representation is:

?

=

[

3

;

2

,

1

,

3

,

1

,

1

,

13

,

2

,

3

,

3

,

2

,

1

,

1

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6

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3

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2

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4

,

362

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2

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4

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8

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6

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30

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50

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1

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6

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3

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3

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2

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7

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2

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3

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1

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3

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2

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…

]

{\displaystyle \psi =[3;2,1,3,1,1,13,2,3,3,2,1,1,6,3,2,4,362,2,4,8,6,30,50,1,6,3,3,2,7,2,3,1,3,2,\dots]\!\,}

(sequence A079587 in the OEIS).

Golden spiral

golden spiral. Another approximation is a Fibonacci spiral, which is constructed slightly differently. A Fibonacci spiral starts with a rectangle partitioned

In geometry, a golden spiral is a logarithmic spiral whose growth factor is ?, the golden ratio. That is, a golden spiral gets wider (or further from its origin) by a factor of ? for every quarter turn it makes.

Golden ratio

Kamil (c. 850–930) employed it in his geometric calculations of pentagons and decagons; his writings influenced that of Fibonacci (Leonardo of Pisa) (c. 1170–1250)

In mathematics, two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two quantities. Expressed algebraically, for quantities ?

a

{\displaystyle a}

? and ?

b

{\displaystyle b}

? with ?

a

>

b

>

0

{\displaystyle a>b>0}

?, ?

a

{\displaystyle a}

? is in a golden ratio to ?

b

{\displaystyle b}

? if

a

+

b

a

=

a

b

=

?

,

{\displaystyle {\frac {a+b}{a}}={\frac {a}{b}}=\varphi ,}

where the Greek letter phi (?

?

{\displaystyle \varphi }

? or ?

?

{\displaystyle \phi }

?) denotes the golden ratio. The constant ?

?

{\displaystyle \varphi }

? satisfies the quadratic equation ?

?

2

=

?

+

1

{\displaystyle \textstyle \varphi ^{2}=\varphi +1}

? and is an irrational number with a value of

The golden ratio was called the extreme and mean ratio by Euclid, and the divine proportion by Luca Pacioli; it also goes by other names.

Mathematicians have studied the golden ratio's properties since antiquity. It is the ratio of a regular pentagon's diagonal to its side and thus appears in the construction of the dodecahedron and icosahedron. A golden rectangle—that is, a rectangle with an aspect ratio of ?

?

{\displaystyle \varphi }

?—may be cut into a square and a smaller rectangle with the same aspect ratio. The golden ratio has been used to analyze the proportions of natural objects and artificial systems such as financial markets, in some cases based on dubious fits to data. The golden ratio appears in some patterns in nature, including the spiral arrangement of leaves and other parts of vegetation.

Some 20th-century artists and architects, including Le Corbusier and Salvador Dalí, have proportioned their works to approximate the golden ratio, believing it to be aesthetically pleasing. These uses often appear in the form of a golden rectangle.

Lucas number

closely related Fibonacci sequence. Individual numbers in the Lucas sequence are known as Lucas numbers. Lucas numbers and Fibonacci numbers form complementary

The Lucas sequence is an integer sequence named after the mathematician François Édouard Anatole Lucas (1842–1891), who studied both that sequence and the closely related Fibonacci sequence. Individual numbers in the Lucas sequence are known as Lucas numbers. Lucas numbers and Fibonacci numbers form complementary instances of Lucas sequences.

The Lucas sequence has the same recursive relationship as the Fibonacci sequence, where each term is the sum of the two previous terms, but with different starting values. This produces a sequence where the ratios of successive terms approach the golden ratio, and in fact the terms themselves are roundings of integer powers of the golden ratio. The sequence also has a variety of relationships with the Fibonacci numbers, like the fact that adding any two Fibonacci numbers two terms apart in the Fibonacci sequence results in the Lucas number in between.

The first few Lucas numbers are

2, 1, 3, 4, 7, 11, 18, 29, 47, 76, 123, 199, 322, 521, 843, 1364, 2207, 3571, 5778, 9349, ... (sequence A000032 in the OEIS)

which coincides for example with the number of independent vertex sets for cyclic graphs

C

n

{\displaystyle C_{n}}

of length

n

?

2

{\displaystyle n\geq 2}

.

Elliott wave principle

led him to conclude that "The Fibonacci Summation Series is the basis of The Wave Principle". Numbers from the Fibonacci sequence surface repeatedly in

The Elliott wave principle, or Elliott wave theory, is a form of technical analysis that helps financial traders analyze market cycles and forecast market trends by identifying extremes in investor psychology and price levels, such as highs and lows, by looking for patterns in prices. Ralph Nelson Elliott (1871–1948), an American accountant, developed a model for the underlying social principles of financial markets by studying their price movements, and developed a set of analytical tools in the 1930s. He proposed that market prices unfold in specific patterns, which practitioners today call Elliott waves, or simply waves. Elliott published his theory of market behavior in the book The Wave Principle in 1938, summarized it in a series of articles in Financial World magazine in 1939, and covered it most comprehensively in his final major work Nature's Laws: The Secret of the Universe in 1946. Elliott stated that "because man is subject to rhythmical procedure, calculations having to do with his activities can be projected far into the future with a justification and certainty heretofore unattainable".

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