### 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dynamic Illustrations Of Some Fibonacci Identities

AMITAVA SARASWATI

St. Paul's Senior Secondary School Indore INDIA

August 29, 2011

AMITAVA SARASWATI 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dy

同 ト イ ヨ ト イ ヨ ト

-

Some of his famous books include **Liber Abaci** which explains the major contributions to algeba by al-Khowarzimi and Abu Kamil.

< ∃> < ∃>

Some of his famous books include **Liber Abaci** which explains the major contributions to algeba by al-Khowarzimi and Abu Kamil.

Flos (Blossom or Flower)

4 E 6 4 E 6

Some of his famous books include **Liber Abaci** which explains the major contributions to algeba by al-Khowarzimi and Abu Kamil.

Flos (Blossom or Flower)

Liber Quadratorum, a book on square numbers (Number Theory)

- 2 2 3 4 2 3 3

Some of his famous books include **Liber Abaci** which explains the major contributions to algeba by al-Khowarzimi and Abu Kamil.

Flos (Blossom or Flower)

Liber Quadratorum, a book on square numbers (Number Theory)

**Practica Geometriae** (Practice of Geometry). Here he employed algebra to solve geometric problems and used geometry to solve algebraic problems, a radical approach for Europe for his day.

化苯丙酸 化苯丙

But the puzzle was made famous by **Sam Lloyd Sr.**, who had presented the problem to the American Chess Congress in 1858

But the puzzle was made famous by **Sam Lloyd Sr.**, who had presented the problem to the American Chess Congress in 1858

A rectangle measuring 13 units by 5 units is cut into four pieces and the pieces are rearranged to form a square . But the side of the square measure 8 units resulting in a fall in area by 1 unit. How do we explain the missing unit ? Let us see this dynamically.

But the puzzle was made famous by **Sam Lloyd Sr.**, who had presented the problem to the American Chess Congress in 1858

A rectangle measuring 13 units by 5 units is cut into four pieces and the pieces are rearranged to form a square . But the side of the square measure 8 units resulting in a fall in area by 1 unit. How do we explain the missing unit ? Let us see this dynamically.

click here to see applet

But the puzzle was made famous by **Sam Lloyd Sr.**, who had presented the problem to the American Chess Congress in 1858

A rectangle measuring 13 units by 5 units is cut into four pieces and the pieces are rearranged to form a square . But the side of the square measure 8 units resulting in a fall in area by 1 unit. How do we explain the missing unit ? Let us see this dynamically.

click here to see applet

#### Fibonacci and Lucas sequences

Let us consider two sequences , Fibonacci and Lucas

Let us consider two sequences , Fibonacci and Lucas

The seeds of Fibonacci sequence are 1 and 1 whereas that of the Lucas sequence are 1 and 3 respectively.

#### Fibonacci and Lucas sequences

Let us consider two sequences , Fibonacci and Lucas

The seeds of Fibonacci sequence are 1 and 1 whereas that of the Lucas sequence are 1 and 3 respectively.

 $F_{n+2} = F_{n+1} + F_n$ 

#### Fibonacci and Lucas sequences

Let us consider two sequences , Fibonacci and Lucas

The seeds of Fibonacci sequence are 1 and 1 whereas that of the Lucas sequence are 1 and 3 respectively.

 $F_{n+2} = F_{n+1} + F_n$ 

 $L_{n+2} = L_{n+1} + L_n$ 

Let us consider two sequences , Fibonacci and Lucas

The seeds of Fibonacci sequence are 1 and 1 whereas that of the Lucas sequence are 1 and 3 respectively.

 $F_{n+2}=F_{n+1}+F_n$ 

 $L_{n+2} = L_{n+1} + L_n$ 

 $F_n = \{ 1, 1, 2, 3, 5, 8, 13, 21, \ldots \}$ 

Let us consider two sequences , Fibonacci and Lucas

The seeds of Fibonacci sequence are 1 and 1 whereas that of the Lucas sequence are 1 and 3 respectively.

 $F_{n+2} = F_{n+1} + F_n$   $L_{n+2} = L_{n+1} + L_n$   $F_n = \{ 1, 1, 2, 3, 5, 8, 13, 21, \dots \}$   $L_n = \{ 1, 3, 4, 7, 11, 18, 29, \dots \}$ 

Consider the matrix 
$$Q = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

AMITAVA SARASWATI 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dy

<ロ> <同> <同> < 回> < 回>

2

Consider the matrix  $Q = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ 

This matrix was first studied by Charles H. King in 1960

Consider the matrix  $Q = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ 

This matrix was first studied by Charles H. King in 1960

$$Q^{2} = Q.Q$$

$$= \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$

Consider the matrix  $Q = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ 

This matrix was first studied by Charles H. King in 1960

$$Q^{2} = Q.Q$$

$$= \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$

$$Q^{3} = Q^{2}Q$$

Consider the matrix  $Q = \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ 

This matrix was first studied by Charles H. King in 1960

$$Q^{2} = Q.Q$$

$$= \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix}$$

$$Q^{3} = Q^{2}Q$$

$$= \begin{bmatrix} 2 & 1 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 3 & 2 \\ 2 & 1 \end{bmatrix}$$

$$Q^n = \left[\begin{array}{cc}F_{n+1}&F_n\\F_n&F_{n-1}\end{array}\right]$$
 also det (Q) = 1 \* 0 - 1 \* 1 = -1

AMITAVA SARASWATI 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dy

< 回 > < 三 > < 三 >

э

$$Q^n = \left[\begin{array}{cc}F_{n+1} & F_n\\F_n & F_{n-1}\end{array}\right]$$
 also det (Q) = 1 \* 0 - 1 \* 1 = -1

 $det\left(Q^{n}\right)=\left(det\left(Q\right)\right)^{n}$ 

\* E > \* E >

э

$$Q^n = \left[ \begin{array}{cc} F_{n+1} & F_n \\ F_n & F_{n-1} \end{array} \right]$$
 also det (Q) = 1 \* 0 - 1 \* 1 = -1

 $det\left(Q^{n}\right)=\left(det\left(Q\right)\right)^{n}$ 

 $F_{n+1}F_{n-1} - F_n^2 = (-1)^n$ 

э

$$Q^{n} = \begin{bmatrix} F_{n+1} & F_{n} \\ F_{n} & F_{n-1} \end{bmatrix}$$

also det(Q) = 1 \* 0 - 1 \* 1 = -1

 $det(Q^n) = (det(Q))^n$ 

 $F_{n+1}F_{n-1} - F_n^2 = (-1)^n$ 

This identity, known as **Cassini's identity** is the driving force behind Sam Lloyd's puzzle.

- 2 2 3 4 2 3 3

-

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

for  $\mu = 1$ ;  $G_n = F_n$ 

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

for 
$$\mu=1;~G_n=F_n$$
  
where F = Fibonacci Number with  $F_1=1$  and  $F_2=1$ 

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

 $\label{eq:general} \begin{array}{l} \mbox{for } \mu = 1; \ {\it G}_n = {\it F}_n \\ \mbox{where } {\rm F} = {\rm Fibonacci \ Number \ with \ } {\it F}_1 = 1 \ \mbox{and \ } {\it F}_2 = 1 \end{array}$ 

for 
$$\mu = 5$$
;  $G_n = L_n$ 

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

 $\label{eq:general} \begin{array}{l} \mbox{for } \mu = 1; \ {\it G}_n = {\it F}_n \\ \mbox{where } {\rm F} = {\rm Fibonacci} \ {\rm Number} \ {\rm with} \ {\it F}_1 = 1 \ {\rm and} \ {\it F}_2 = 1 \end{array}$ 

for  $\mu = 5$ ;  $G_n = L_n$ where L = Lucas Number with  $L_1 = 1$  and  $L_2 = 3$ 

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

 $\label{eq:general} \begin{array}{l} \mbox{for } \mu = 1; \ {\it G}_n = {\it F}_n \\ \mbox{where } {\rm F} = {\rm Fibonacci} \ {\rm Number} \ {\rm with} \ {\it F}_1 = 1 \ {\rm and} \ {\it F}_2 = 1 \end{array}$ 

 $\label{eq:Gamma} \begin{array}{l} \mbox{for } \mu=5; \ \mbox{$G_n=L_n$} \\ \mbox{where } L=\mbox{Lucas Number with } L_1=1 \ \mbox{and } L_2=3 \end{array}$ 

click here for applet

Let  $G_n$  stand for a generalized Fibonacci number , then Cassini's generalized identity becomes

$$G_{n-1}G_{n+1} - G_n^2 = \mu (-1)^n$$

where  $\mu$  is the characteristic

 $\label{eq:general} \begin{array}{l} \mbox{for } \mu = 1; \ {\it G}_n = {\it F}_n \\ \mbox{where } {\rm F} = {\rm Fibonacci} \ {\rm Number} \ {\rm with} \ {\it F}_1 = 1 \ {\rm and} \ {\it F}_2 = 1 \end{array}$ 

 $\label{eq:Gamma} \begin{array}{l} \mbox{for } \mu=5; \ \mbox{$G_n=L_n$} \\ \mbox{where } L=\mbox{Lucas Number with } L_1=1 \ \mbox{and } L_2=3 \end{array}$ 

click here for applet

# **FIBONACCI VECTORS**

### and the

## **R** Matrix

AMITAVA SARASWATI 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dy

Let us consider the matrix 
$$R = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$$

AMITAVA SARASWATI 2nd International GeoGebra Conference 2011 Hagenberg near Linz Austria Dy

Let us consider the matrix  $R = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$ 

The R matrix was introduced by Hoggatt and Ruggles in 1963

Let us consider the matrix  $R = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$ 

The R matrix was introduced by Hoggatt and Ruggles in 1963

Also consider a vector  $\vec{f} = [F_{n+1} \ F_n]$ 

and a vector  $\vec{l} = [L_{n+1}L_n]$ 

Let us consider the matrix  $R = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$ 

The R matrix was introduced by Hoggatt and Ruggles in 1963

Also consider a vector  $\vec{f} = [F_{n+1} \ F_n]$ 

and a vector  $\vec{l} = [L_{n+1}L_n]$   $[F_{n+1} F_n] \begin{bmatrix} 1 & 2\\ 2 & -1 \end{bmatrix}$  $= [F_{n+1} + 2F_n \ 2F_{n+1} - F_n]$ 

Let us consider the matrix  $R = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$ 

The R matrix was introduced by Hoggatt and Ruggles in 1963

Also consider a vector  $\vec{f} = [F_{n+1} \ F_n]$ 

and a vector  $\vec{l} = [L_{n+1}L_n]$  $\begin{bmatrix} F_{n+1} & F_n \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$   $= [F_{n+1} + 2F_n & 2F_{n+1} - F_n]$   $= [L_{n+1}, L_n]$ 

click here

#### Acknowledgements

I express my sincere thanks to Dr. I.K.Rana and Dr. S. Shirali for their relentless support in this project

#### References

A Primer On Number Sequences , Dr. Shailesh Shirali

Fibonacci And Lucas Numbers With Applications , Prof. Thomas Koshy