An Ancient Calculator: The Quipu

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April 1, 2002

Adventures in Supercomputing Challenge
Project Number 092
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Acknowledgements

The authors wish to acknowledge the following individuals for the guidance provided in the selection of a suitable topic, development of the computer code, adaptation to the computer based analyses, and assistance provided in the overall preparation of this report:

- Mrs. Peggy Larisch – Teacher
- Mr. Daniel Houch – Mentor

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E.0 Executive Summary

The team has developed a program to represent a "virtual quipu." Since information on the quipu and the Incas is lacking, it was an interesting topic for the team. The project on Incas began as a class project to understand how the AiS challenge works. The team decided to take on the project as a challenge to better understand the Incan culture. First, extensive research was done on the mysterious civilization through the internet and a book. The team found research to be a difficult task because of the lack of knowledge in this area of history. The best, most in depth resource was the book *Mathematics of the Incas: Code of the Quipu* by M. and R. Ascher. The research was then used to develop a program to represent a modern computer version of a quipu while keeping basic concepts used by the Incas. The program is used to keep a census and find averages of the number of men, women, and children per family per village in a civilization. The division of the Incas was used to find the average, by dividing into parts and using only whole numbers. The division could be considered a form of reverse adding. The team used C++ to write an original program, but found limitations that restricted graphic capabilities.

1.0 Introduction

1.1 Abstract

It is often wondered how ancient civilizations kept track of their food stock, population, or livestock. The Incas used a mechanism called a quipu, a device made of string tied in knots to represent a number, pronunciation key, or word. They could be added, subtracted, even multiplied and divided using complex matrix algebra, or they could tell a story of their history. Quipus are the only physical records today of the Incas. The goal in this project is to computerize the quipu and demonstrate the intricate minds of the Incas by using their original arithmetic to find totals and averages of a census of a community. The automated quipu will then output the graphics of the data to resemble a real quipu.

1.2 Purpose

The team has chosen to build a virtual quipu in order represent the ancient Incan mathematics, which few know about. This project started as a class assignment to read about, and create quipus in order to get a feel for the AiS Challenge. After reading the book *Mathematics of the Incas: Code of the Quipu*, this team has taken on the challenge of programming the mathematics that the ancient Incan culture used for census, inventory, etc. The team chose this project idea because they were drawn into the idea of alternate mathematics, and the neat recording method the Incas used to employ. Research over the Internet and other sources was conducted to find out as much information as possible to get a better idea of Incan culture and later to apply this information to the program.

1.3 Computer Program

The computer program is written in the C++ language because the Advanced Computers class was studying this language first semester. The program is struct oriented with each quipu being a separate struct. The user is allowed to input data that will keep a census of a civilization that includes many villages and families. The user then will be able to find totals or averages. C++ could not be used for the graphics as problems were faced when libraries could not be loaded into the C++ compiler. This program is a completely original code developed and prepared by the team.

2.0 Problem Statement

Information about the Incas, the Incan civilization and their society is not extensive. Actual archeological and historical evidence of their existence is even less common. Especially in the manner in which the Inca communicated, that is, it appears that there is very limited "written" techniques employed; however, once system that has been discovered is that referred to as the Quipu. Quipus are the only physical evidence of their semi-written language, or any other type of records. There are no detailed written records that have been found to explain exactly how to use a quipu, only the quipus themselves and occasional references from archeological and historical sources. Consequently, the quipu, how it was used in daily life and its value to society are not well understood.

There is no definite support that a quipu was used like we think it does. Everything is based on hypothesis. Since there is little knowledge of these quipus, the team decided to try and recreate a virtual quipu to gain a better understanding of how the quipus worked and were created. The "study of quipus can yield an understanding of the general recording system and some of the mathematical concepts, structural principles, and expressive techniques that underlie it"[1].

3.0 Research

3.1 The Incas

The Incas were the largest and most sophisticated civilization of the pre-Colombian era. They were ruled by a monarchy, which they believed was granted by divine right. They were centered at Cuzco, Peru and controlled over 2000 miles throughout the Andes Mountains. The native language was Quechua. A very advanced aspect of them was that they used storehouses to keep food for when goods were not available. When crops were good and there was a surplus of food, it was stored for use when times became rough[1]. Another interesting fact, which also aided their disappearance, was that they were very accepting of different cultures and blended in well. Instead of dominating a region with an iron fist and making the conquered people gain Incan culture, they adapted their own culture to fit the lifestyles already established by the captives. Along with this, in 1535 the Spanish army conquered the Incas with the rifle[2].

3.2 Quipus

Quipus are the only artifacts of a "written language" that we have today of the Incas. The quipu, which is Quechua for knot, was a recording device made of knots on wool or cotton strings. The recording device consists of a main cord, top cord, pendant cords, subsidiary cords, subsidiaries of subsidiaries, etc. The quipus were ideal because of their portability and various uses. They were used to keep inventory, census, loom patterns, or tell a story. Quipus often recorded numerical data and even folklore or stories of the Incas. Whenever a quipu was used to relate a story, knots would be placed in arrangement according to syllables or sounds[3].

The base of a quipu is the main cord. It is generally much thicker than the hanging pendant cords. Pendant cords that hang upwards are called top chords and cords hanging from the pendant cords are subsidiary cords[1]. The top cords usually associate pendant cords and represent a sum or total[1]. Each cord is color coded, which makes the quipus so spectacular and expands the utility of the quipu. The color-coding is used to distinguish among the information provided on the quipu. The quipumaker would use general colors from dye and form additional colors by twisting colors together. Twisting in one direction would cause a candy cane effect, while twisting in the opposite direction will create a mottled effect[1].

On each pendant cord, a number is recorded by tying various knots in certain positions on the cord. The knots are separated into clusters by spaces that represent different powers of ten (1's, 10's, 100's, 1000's, etc.). A long knot is used in the single digit position (1-9). In the long knot, the number is the number of twists in the knot. Therefore, a single twist, or figure eight knot, would represent the number one. Single knots represent numbers in every other position[1]. If there is no knot in a position, it represents zero. The way the quipu is read is the highest value is positioned closest to the main cord[1]. So, the pendant cords would read from top to bottom and the top cords would read from bottom to top. (*see Appendix 1*)

In order to make such elaborate recording devices, the quipumaker had to have a variety of special skills. The quipumaker was able to use materials from the environment that were ideal for quipus. Since the quipu was very light it was very transportable adding to the overall utility of the device. Rather than using stone or animal skins, the Incas used lightweight cotton or wool[1]. The quipumaker also had to have a keen eye for color. Unlike the Sumerians who used no color, or the Egyptians who used two colors, the Incas used hundreds of colors[1]. Every quipu was made differently, but when read, it would come out to the same correct summation. Spacing and color of knots were vital to the data input. Because of the importance of quipus in Incan society, the quipumaker held a position of privilege[1]. The quipumaker worked in many places and was usualy responsible for those who worked under him[1].

Knowledge is very limited in this area, as no one really knows how the story quipus work[4]. The Spanish destroyed much of the evidence during their conquest because the quipus were believed to be the "work of the devil"[1].

4.0 Method of Solution

3.1 Mathematical Model

The majority of the mathematical concepts used by the Incas were acquired by studying quipus. It is obvious that the quipu employed traditional addition and subtraction techniques to find sums; furthermore, there is evidence that the quipu also incorporated division into parts and use of ratios. The Incas would evenly divide a number into parts and disregard decimals. For example, the number 13 evenly divided into three parts would be 4, 4, and 5. The division of larger numbers would be done by halving the number first, then dividing it into even parts. The number 102 would first be divided into two parts of 51. Then 51 would be divided into four parts of 12,13,13, and 13[1]. This technique involves a rather sophisticated system of mathematics; particularly division and multiplication are intimately connected. Four doubled would be eight and half of eight would be four. Since the Incas did not use decimals or remainders, numbers were rounded to the nearest whole number. Therefore, half of nine would also be four and five[1]. Because of this, the numbers recorded on a quipu may not be considered as accurate as if done by Western math of today.

The equation used in the C++ program was as follow:

- r = x/village; where x is the total number of men, women, or children and village is the number of villages
- r = z + r
- div = x –z
- r is displayed village – 1 times
- div is displayed as the last part

All math was check numerous times by hand calculations.

3.2 Computational Methods

A computer program was developed to resemble a "virtual" quipu. The program was devised in C++ (*see Appendix* 2). Structs were used to obtain data and store into vectors and later display the data input. The program first asks the user to input the number of villages in the civilization he/she is keeping census for. A "for" loop follows and for every village the user is then asked to input the number of families per village, followed by a nested "for" loop. A funtion is then called that asks the user to input the number of men, women, and children per family, which is entered into a vector. While the numbers are being entered, the variables census, totmen, totwomen, and totkids are added to find the totals for the entire census, men, women, and children. Once the figures are entered, a menu is brought up using the switch case that allows the user to either find the totals, the averages of people per village, or display the data they have input.

Case 1: Find the totals. A nested switch case is used to find either the total number of men, women, children, or the entire census. A "while" statement is used in order to allow the user to view the totals as long as necessary.

Case 2: Find the averages. "If" statements and a "while" statement are used to find the averages of men, women, children, or all people per village. The team tried to follow Incan mathematics in the sense of dividing into parts and using only whole numbers. Although considered a simplified version of mathematics, it took five variables and two different methods. The first method is for numbers greater than thirty. The Incans would first halve large numbers and then proceed to divide into smaller units. The second method is for numbers less than thirty. The variables used were as follows:

- x – represented either the total men, women, children, or census
- village – the number of villages entered by the user
- r – x divided by village
- z – the totals of the outputted r's
- div – x minus z

A "for" loop was used to output the averages into parts, which simulates the Inca technique.

Case 3: Display the user input. A function is called that outputs the data stored in the vector. The number of men, women, and children per family are displayed, plus, the totals for each.

A "while" statement surrounding the entire main function allows the user to either add more information or quit.

The structs used are:

- InfoType – declares the variables for men, women and children
- QuipuType – the vector is declared. Also, the variables to resize the vector when necessary.

The functions used are:

- GetData – for user input of men, women, children
- display – cout of men, women, and children stored in the vector
- displayquipu – displays entire vector
- addfamily – allows resizing of the vector

All code is completely original written by the team specifically for this project.

5.0 Results

One of the principal uses of the quipu by the Incas was the maintenance of a census record. Therefore, the virtual quipu developed by this project, also created a record keeping technique, which could then be compared to actual quipus to verify technique and application of data. The virtual quipu, like many quipus of the past, keeps a census. If drawn out, the quipu would be vertical in structure and have four levels. The first level, or pendant cords, represents the villages. The second level, or subsidiaries of the village cords, represents the families. The third level, or subsidiaries of the family cords, represents men, women, and children. Each level is represented by a different color, and the knots for men, women, or children are different colors.

The program follows the mathematical concepts used by the Incas. Only whole numbers were used in finding the averages. Also, rather than simply dividing, the number was divided into parts. The output of the average number per village is output in several parts, depending on the number of villages entered.

6.0 Conclusions

6.1 Mathematical Models

The "simplified" form of arithmetic used by the Incas was incorporated into the program. Traditional addition was used in order to find the totals of men, women, children, and the entire census. In order to find the averages, the total number of people was divided into parts equaling the total number of villages. If a number was larger than thirty, it was halved first in order to make it easier to work with. All equations used were verified by hand calculations to validate the accuracy of the program.

6.2 Computer Program

The team successfully created a "virtual" quipu using original C++ coding. The C++ program created by the team was overall useful in understanding the use of quipus. The program was written in C++ because this language is very adaptable to a range of applications and is uniquely suitable to developing an original program as was required for this project. Vectors, structs, fuctions, and various simple statements were used in developing the program. The program allows the user to input the number of men, women, and children in a family in a village where the census is being taken. It displays the numbers per family and also allows the user to find totals and averages of men, women, children, and the entire census. The quipu was an important aspect in Incan communication and by learning more about their beneficial quipu, we can perhaps learn more about the mystifying culture.

5.4 Recommendations

Since the libraries for graphics were not available in C++, an actual drawn out quipu is not available. Based on the study performed for this project and the requirements for visual presentation that was not available with the C++ program, it is recommended that JAVA be utilized coupled with an applet to display the information input.

References

1. Ascher M and R, "Mathematics of the Incas: Code of the Quipu." Mineola, New York, 1997.

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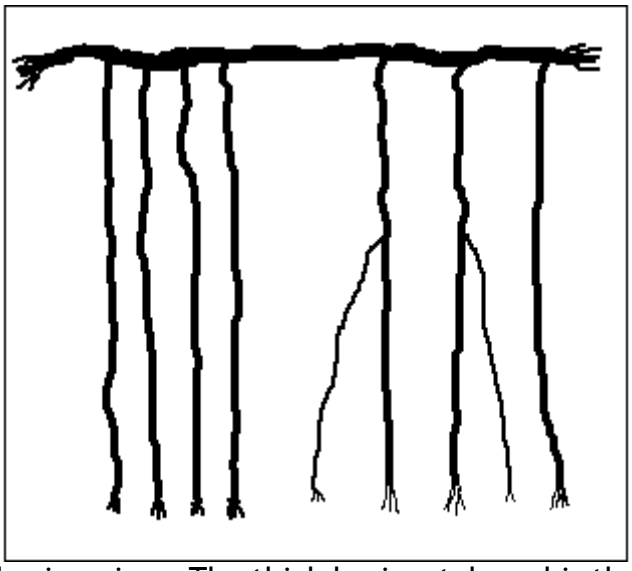
4. O'Connor, J.J. and E.F. Robertson. "Mathematics of the Incas." JOC/EFR January 2001. http://www.history.mcs.standrews.ac.uk/history/HistTopics/Inca_mathematics.html. Viewed on March 8, 2002.

5. Storey, Alice. "Quipu: A Modern Mystery." Simon Fraser University, 1999. http://www.sfu.ca/archaeology/museum/laarch/inca/quipue.html. Viewed on March 8, 2002.

APPENDICES

Appendix 1 – The Quipu
Appendix 2 – C++ Program

Appendix 1
Structure of the Quipu



This represents a basic quipu. The thick horizontal cord is the main cord, while the vertical cords are the pendant cords. The thinner cords hanging from various pendant cords are subsidiary cords.

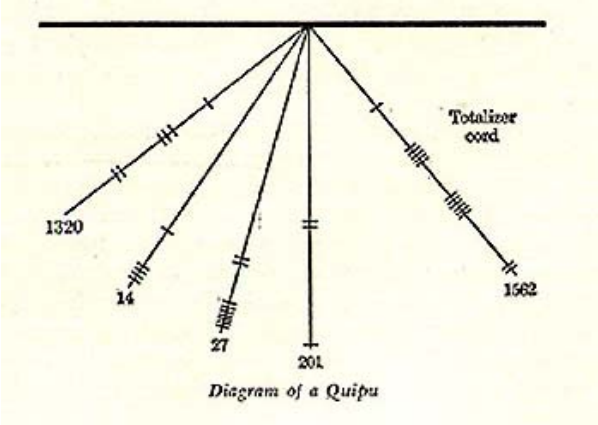


Diagram of a Quipu

This is a closer look at the pendant cords. The lines represent the knots on the cords. The significance of spacing is well represented. The cord to the far right would be a top cord that represents the sums of the data on the quipu.

Appendix 2
C++ Mathematics Code

```
/* Rhiannon Houch and Ruben Guadiana
   Team #092
   An Ancient Calculator

   --This program simulates a quipu recording census for a civilization.
  It will count the total census, along with total men, women, and
children --
*/

#include <iostream.h>
#include <math.h>
#include <stdlib.h>
#include <vector.h>


struct InfoType
{
 int men;
 int women;
 int kids;
};


struct QuipuType
{
 QuipuType();
 const int SizeChange;
 int NumPeople;
 vector<InfoType> census; //quipu info
};

QuipuType::QuipuType()
 :SizeChange(5), census(5), NumPeople(0)
{
}

//enter data
void GetData(InfoType &Info)
{
   cout<<"Enter the number of men: ";
   cin>>Info.men;
   cout<<"Enter the number of women: ";
```

```
   cin>>Info.women;
   cout<<"Enter the number of children: ";
   cin>>Info.kids;
}

//display data
void display(const InfoType &Info)
{

 cout<<"\t "<<Info.men<<" \t "<<Info.women<<" \t "<<Info.kids<<endl;
 cout<<"\n"<<endl;

}

void displayquipu(const QuipuType &Quipu)
{

 for (int x=0; x<Quipu.NumPeople; x++)
 {
    cout<<"Family "<<x+1;
    display(Quipu.census[x]);
 }
}

void addfamily(QuipuType &Quipu, const InfoType &NewFamily)
{
 Quipu.census[Quipu.NumPeople]=NewFamily;
 Quipu.NumPeople++;
}

int main()
{
  //declare variables
  QuipuType Quipu;
  InfoType Info;

  int r; //for while statement
  int math; //for switch statement
  int w; //for while
//explanation
  cout<<"\n";
  cout<<"--This program will simulate an Incan Quipu."<<endl;
  cout<<"You are back to time before written language.  The King has asked
you to take the census of the entire Incan civilization, which spans over
2000 miles. Since carrying a stone would be inconveniant, you make a
quipu, a bundle of tied knots in string.--\n\n\n"<<endl;
```

```
 //variables for totals
 int totmen=0;
 int totwomen=0;
 int totkids=0;
 int census=0;


while (r!=2)
{
 //prompt user
 int village;
 int family;
 int V[500];
 cout<<"Enter the number of villages you wil be counting: ";
 cin>>village;

 for (int v=0; v<village;v++)
 {
  cout<<"\nFor Village "<<v+1<<"...\n"<<endl;

  cout<<"Enter the number of families in this village: ";
  cin>>V[v];
  family=V[v];

  for(int f=0; f<family; f++)
  {
   cout<<"For Family "<<f+1<<"..."<<endl;
 //call function
   GetData(Info);
   addfamily(Quipu, Info);
 //totals
   totmen = totmen + Info.men;
   totwomen = totwomen + Info.women;
   totkids = totkids + Info.kids;
   census = totmen+totwomen+totkids;
  } //close family for loop
 } //close village for loop

  //do action
  int z;
  while (z!=0)
  {
  cout<<"\nWhat would you like to do with this information?\n"<<endl;
  cout<<"\t1. Find totals\n"<<endl;
  cout<<"\t2. Find Averages\n"<<endl;
```

```
cout<<"\t3. Display data\n"<<endl;
cout<<"0 to Quit"<<endl;
cin>>z;

switch(z)
{

case 1: cout<<"\t1. Find the total census\n";
        cout<<"\t2. Find the total number of men\n";
        cout<<"\t3. Find the total number of women\n";
        cout<<"\t4. Find the total number of children\n\t";
        cout<<"\t0 to Quit"<<endl;
        cin>>math;


        while (math!= 0)
        {  //open while

        switch (math)
        {  //open switch
        case 1: cout<<"There are "<<census<<" people total."<<endl; break;
        case 2: cout<<"There are "<<totmen<<" men total."<<endl; break;
        case 3: cout<<"There are "<<totwomen<<" women total."<<endl; break;
        case 4: cout<<"There are "<<totkids<<" children total."<<endl; break;
        } //close switch

        cout<<"\nNow what would you like to find?\n";
        cout<<"\t1. Find the total census\n";
        cout<<"\t2. Find the total number of men\n";
        cout<<"\t3. Find the total number of women\n";
        cout<<"\t4. Find the total number of children\n";
        cout<<"\t5. Find the total number grandchildren\n";
        cout<<"\t\t0 to Quit"<<endl;
        cin>>math;
        } //close while
        ;break;
case 2: int x;
        int num;
        cout<<"What would you like to find the average of?\n"<<endl;
        cout<<"\t1. Men\n";
        cout<<"\t2. Women\n";
        cout<<"\t3. Children\n";
        cout<<"\t4. All People\n"<<endl;
        cin>>num;
        if(num==1)
        x=totmen;
```

```
        else if (num == 2)
        x = totwomen;
        else if (num == 3)
        x = totkids;
        else if (num==4)
        x = census;
        else
        cout<<"That's not an option"<<endl;
      //declare variables
         int y;
         int z;
         int r;
         int s;
         int div;

        //for #s greater than 30
        if (x>30)
        {
        x=x/2;
        cout<<"Since the number is greater than 30, we will split the number in
half"<<endl;
       cout<<"The average per village is: "<<endl;
       for (int i=1; i<village; i++)
       {
       r=x/village;
       cout<<r<<endl;
       z=z+r;
       }
       div= x-z;

      cout<<div<<endl;

      }
      else
      {
      cout<<"The average per village is: "<<endl;
      for (int i=1; i<village; i++)
      {
      r=x/village;
      cout<<r<<endl;
      z=z+r;
      }
      div= x-z;

      cout<<div<<endl;
      }; break;
```

```
  case 3:
       cout<<"\n  ****************************************\n"<<endl;
       cout<<"\t\tMen\t Women\t Children\n"<<endl;

       displayquipu(Quipu);
       cout<<"Totals:   \t "<<totmen<<"\t "<<totwomen<<"\t "<<totkids<<endl;
       cout<<"\nTotal Census: "<<census<<"\n"<<endl;
       cout<<"\n  ****************************************\n"<<endl;
       break;

  } //close switch
 } //close while (z)
//see if the user is done

  cout<<"Would you like to (1) Enter new data or (2) Quit?"<<endl;
  cin>>r;
  }// close while (r)

    return(0);
}//close program
```