One of the fundamental theorems of probability is the Central Limit Theorem. This theorem says that if Sn is the sum of n mutually independent random variables, then the distribution function of Sn, for a large n, is well-approximated by a certain type of continuous function known as a normal density function, which is given by the formula

Formula does not parse

We will demonstrate this using a C program and the following problems.

Distribution of Sum of Random Variables:

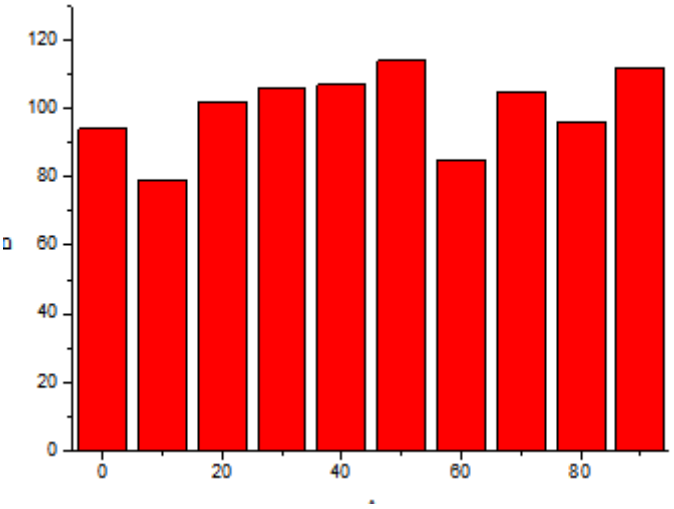
Case 1
1. Let M_i = a_i be marks of n students in one subject, i=1,2,...n (n=1000).
2. Let a_i be the uniformly distributed random numbers between 0 and m (m is the maximum marks=100).
3. Find the frequency distribution of M.

CODE:

```
/*********************************************
****Random Marks Frequency Distribution***
*********************************************/
#include<stdio.h>
#include<math.h>
/**Function that generates a random number.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement(offset) factor
**/
int rand(int r0, int a, int m, int c){
        int r1=(a*r0+c)%m;
        return r1;
}
/**Function that generates random numbers in a given range: [min,max], given a seed r0,
and stores them in an array that is passed as an argument.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement factor
n: no. of random numbers to be generated
x[n]: array that will store the random numbers
min: lower limit for random nos.
max: upper limit for random nos.
**/
void randomNos(int r0, int a, int m, int c, int n, int x[n], int min, int max){
        int r1=rand(r0,a,m,c);
        int r2=min+((max-min+1)*r1)/m;
        int i;
        for(i=0;i<n;i++){
                x[i]=r2;
                r1=rand(r1,a,m,c);
```

```
                r2=min+((max-min+1)*r1)/m;
        }
}
main(){
        int min, max, n, a=1093, m=86436, c=18257, r0=43;
        printf("Enter the lower limit:\n");
        scanf("%d",&min);
        printf("Enter the higher limit:\n");
        scanf("%d",&max);
        printf("Enter the no. of random numbers required:\n");
        scanf("%d",&n);
        int random[n];
        randomNos(r0, a, m, c, n, random, min, max);
        FILE *fp=NULL;
        fp=fopen("marks.txt","w");
        int i,j;
        //printf("The random numbers between %d and %d are:\n",min, max);
        for(i=0;i<n;i++){
                fprintf(fp,"%d\n",random[i]);
        }
        //Begin distribution calculations within different intervals
        int h=10; //width of interval
        int count[10]; //10 intervals of width 10
        for(j=0;j<10;j++){
                count[j]=0;
                for(i=0;i<n;i++){
                        if(j!=9){
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=random[i])&&(random[i]<(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
                        } else{
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=random[i])&&(random[i]<=(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
                        }
                }
        }
        FILE *fp2=NULL;
        fp2=fopen("randMarksDistribution.txt","w");
        for(i=0;i<10;i++){
                fprintf(fp2,"%d\t%d\n",i*h,count[i]);
                //printf("%d\n",count[i]);
        }
}
```

OUPUT:




```
Enter the lower limit:
0
Enter the higher limit:
100
Enter the no. of random numbers required:
1000
```

Case 2

1. Let M_i = a_i + +b_i be total marks of n students in TWO subjects, i=1,2,...n (n=1000).
2. Let each of a_i and b_i be the uniformly distributed random numbers between 0 and m (m is the maximum marks of each subject=50).
3. Find the frequency distribution of M.

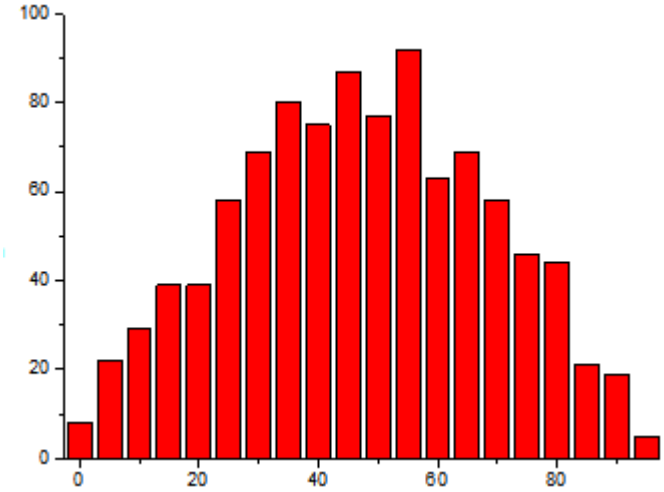
CODE:

```
/*********************************************
****Random Marks Frequency Distribution***
*********************************************/
#include<stdio.h>
#include<math.h>
/**Function that generates a random number.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement(offset) factor
**/
int rand(int r0, int a, int m, int c){
        int r1=(a*r0+c)%m;
        return r1;
}
/**Function that generates random numbers in a given range: [min,max], given a seed r0,
and stores them in an array that is passed as an argument.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement factor
n: no. of random numbers to be generated
x[n]: array that will store the random numbers
```

```
min: lower limit for random nos.
max: upper limit for random nos.
**/
void randomNos(int r0, int a, int m, int c, int n, int x[n], int min, int max){
        int r1=rand(r0,a,m,c);
        int r2=min+((max-min+1)*r1)/m;
        int i;
        for(i=0;i<n;i++){
                x[i]=r2;
                r1=rand(r1,a,m,c);
                r2=min+((max-min+1)*r1)/m;
        }
}
main(){
        int min, max, n, a=1093, m=86436, c=18257, r0=43;
        printf("Enter the lower limit:\n");
        scanf("%d",&min);
        printf("Enter the higher limit:\n");
        scanf("%d",&max);
        printf("Enter the no. of random numbers required:\n");
        scanf("%d",&n);
        int ai[n];
        int bi[n];
        int Marks[n];
        randomNos(0, a, m, c, n, ai, min, max);
        randomNos(2000, a, m, c, n, bi, min, max);
        FILE *fp=NULL;
        fp=fopen("marks2.txt","w");
        int i,j;
        //printf("The random numbers between %d and %d are:\n",min, max);
        for(i=0;i<n;i++){
                Marks[i]=ai[i]+bi[i];
                fprintf(fp,"%d\n",Marks[i]);
        }
        //Begin distribution calculations within different intervals
        int h=5; //width of interval
        int count[20]; //10 intervals of width 10
        for(j=0;j<20;j++){
                count[j]=0;
                for(i=0;i<n;i++){
                        if(j!=19){
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=Marks[i])&&(Marks[i]<(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
                        } else {
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=Marks[i])&&(Marks[i]<=(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
```

```
                        }
                }
        }
        FILE *fp2=NULL;
        fp2=fopen("randMarksDistribution2.txt","w");
        for(i=0;i<20;i++){
                fprintf(fp2,"%d\t%d\n",i*h,count[i]);
                //printf("%d\n",count[i]);
        }
}
```

OUTPUT:




```
Enter the lower limit:
0
Enter the higher limit:
50
Enter the no. of random numbers required:
1000
```

Case 3

1. Let M_i = a_i + +b_i +c_i + d_i + e_i + f_i + g_i +h_i +j_i + k_i be total marks of n students in TEN subjects, i=1,2,...n (n=1000).
2. Let each of a_i, b_i, c_i, ……k_i be the uniformly distributed random numbers between 0 and m (m is the maximum marks of each subject=10).
3. Find the frequency distribution of M.

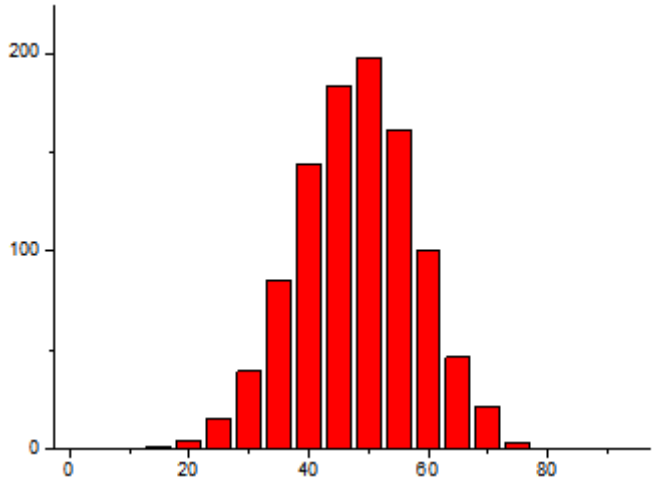
CODE:

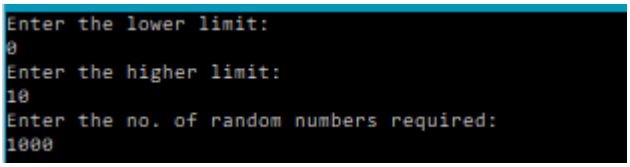
```
/*********************************************
****Random Marks Frequency Distribution***
*********************************************/
#include<stdio.h>
#include<math.h>
/**Function that generates a random number.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement(offset) factor
**/
```

```
int rand(int r0, int a, int m, int c){
        int r1=(a*r0+c)%m;
        return r1;
}
/**Function that generates random numbers in a given range: [min,max], given a seed r0,
and stores them in an array that is passed as an argument.
Parameters:
r0: initial (first) seed
a: scale factor , so that a*r0 give the first random number
m: gives the max. value of random numbers that can be generated (m-1)
c: additional displacement factor
n: no. of random numbers to be generated
x[n]: array that will store the random numbers
min: lower limit for random nos.
max: upper limit for random nos.
**/
void randomNos(int r0, int a, int m, int c, int n, int x[n], int min, int max){
        int r1=rand(r0,a,m,c);
        int r2=min+((max-min+1)*r1)/m;
        int i;
        for(i=0;i<n;i++){
                x[i]=r2;
                r1=rand(r1,a,m,c);
                r2=min+((max-min+1)*r1)/m;
        }
}
main(){
        int min, max, n, a=1093, m=86436, c=18257, r0=43;
        printf("Enter the lower limit:\n");
        scanf("%d",&min);
        printf("Enter the higher limit:\n");
        scanf("%d",&max);
        printf("Enter the no. of random numbers required:\n");
        scanf("%d",&n);
        int A[10*n];
        int Marks[n];
        randomNos(r0, a, m, c, 10*n, A, min, max);
        FILE *fp=NULL;
        fp=fopen("marks3.txt","w");
        int i,j;
        //printf("The random numbers between %d and %d are:\n",min, max);
        for(j=0;j<n;j++){
                Marks[j]=0;
                for(i=j;i<10*n;i=i+n){
                        Marks[j]=Marks[j]+A[i];
                }
                fprintf(fp,"%d\n",Marks[j]);
        }
        //Begin distribution calculations within different intervals
        int h=5; //width of interval
        int count[20]; //10 intervals of width 100
        for(j=0;j<20;j++){
                count[j]=0;
                for(i=0;i<n;i++){
```

```
                        if(j!=19){
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=Marks[i])&&(Marks[i]<(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
                        } else {
                                //find out the number of randomnumbers within an
interval
                                if((j*h<=Marks[i])&&(Marks[i]<=(j+1)*h)){
                                        count[j]++;  //find out the number of
randomnumbers within an interval
                                }
                        }
                }
        }
        FILE *fp2=NULL;
        fp2=fopen("randMarksDistribution3.txt","w");
        for(i=0;i<20;i++){
                fprintf(fp2,"%d\t%d\n",i*h,count[i]);
                //printf("%d\n",count[i]);
        }
}
```

OUTPUT:





Through the above problems, it's pretty much apparent that as the number of random variables whose sum is being taken increases their distribution tends towards the normal (Gaussian) distribution.

References:

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https://www.investopedia.com/terms/c/central_limit_theorem.asp
https://www.dartmouth.edu/~chance/teaching_aids/books_articles/probability_book/Chapter9.pdf

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