

```

clear all
%27
imax = 33;
nmax = 24;
tic;
timedur = toc;
for i=1:imax
    tic;

    if i <= nmax
        [Is(i),pi_me(i),pi_er(i),timepi(i),Vc,points]=Pi_spheref(2^i);
        if i == 14
            figure();
            plot3(Vc(1,points),Vc(2,points),Vc(3,points),'rx');
            hold on;
            plot3(Vc(1,~points),Vc(2,~points),Vc(3,~points),'b. ');
            hold off;
            legend('Points in','Points out','Location','Best');
            title('MC simulation data for Pi');
        end
    else
        nloops = 2^(i-nmax);
        %disp(num2str(nloops));
        [Ib,pi_meb,pi_erb,timepib,Vcb,pointsb]=Pi_spheref(2^nmax);
        sumbin = sum(pointsb);
        stdbin = std(pointsb);

        parfor ia=2:nloops
            %disp('In loop');
            [Ia,pi_mea,pi_era,timepia,Vca,pointsa]=Pi_spheref(2^nmax);
            %Ib = Ib + Ia;
            sumbin2(ia) = sum(pointsa);
            %stdbin2(ia) = sqrt((stdbin^2+std(pointsa)^2)/2);
            stdbin2(ia) = std(pointsa);
            timepib = timepib+timepia;
            %Vcb = Vcb + Vca;
            %pointsb = pointsb + pointsa;
        end
        sumbin = sumbin + sum(sumbin2);
        stdbin = sqrt((stdbin^2+sum(stdbin2.^2))/nloops);
        Ntotal = 2^i;
        pi_meb = 6*sumbin/(Ntotal); % The calculated values of Pi
        pi_erb = 6*stdbin/sqrt(Ntotal); %The Standard Error of Pi
        [Is(i),pi_me(i),pi_er(i),timepi(i),Vc,points] = deal(Ib,pi_meb,pi_erb,timepib,Vcb,pointsb);
    end
end

```

```

        timedur=toc;
        clc;
        fprintf('%.2f%% Completed, Estimated remaining time %.2f minutes',100*i/imax,(timedur*2
end

% [I_sorted, I_order] = sort(Is);
% pi_me = pi_me(I_order);
% pi_er = pi_er(I_order);
% timepi = timepi(I_order);

for o=1:imax
    fprintf('Calculated Pi is %.8f with a Standard Error of %.8f and actual Pi is %.8f \n',P
end

figure();
errorbar(2.^(1:imax),pi_me,pi_er,'o');
title('Calculated value of Pi and errors');
set(gca, 'XScale', 'log');
set(gca, 'YScale', 'log');
xlabel('Number of vectors');
ylabel('Value of Pi');
hold on;
plot([2^1,2^imax],[pi,pi],'r--');
legend('MC Pi','Pi','Location', 'Best');
figure();
yyaxis left;
plot(2.^(1:imax),timepi);
title('Total run time and error');
set(gca, 'XScale', 'log');
set(gca, 'YScale', 'log');
xlabel('Number of vectors');
ylabel('Time calculating Pi (s)');
yyaxis right;
plot(2.^(1:imax),pi_er);
ylabel('Error in Pi');
set(gca, 'YScale', 'log');
legend('Time','Error','Location', 'Best');

function [M,pi_me,pi_er,timeout,Vc,pointers]=Pi_spheref(N)

%Calculate the value of Pi using MonteCarlo comparing the volumes of a
%sphere and a cube
tic;
%N is the number of random vectros to create
M=N;
Vc = 2*rand(3,N)-1; %The 3D vectors in the (-1,1) region

```

```

Norm = sqrt(Vc(1,:).^2+Vc(2,:).^2+Vc(3,:).^2);%Magnitude of vectors
pointers = Norm<1;%The vectros with a magnitude less than 1, inside the sphere
% Vc_in = Vc(pointers);%The positions of the points inside the sphere
% Vc_out = Vc(1-pointers);%The points outside
pi_me = 6*sum(pointers)/N;% The calculate values of Pi
pi_er = 6*std(pointers)/sqrt(N); %The Standard Error of Pi
timeout=toc;
end

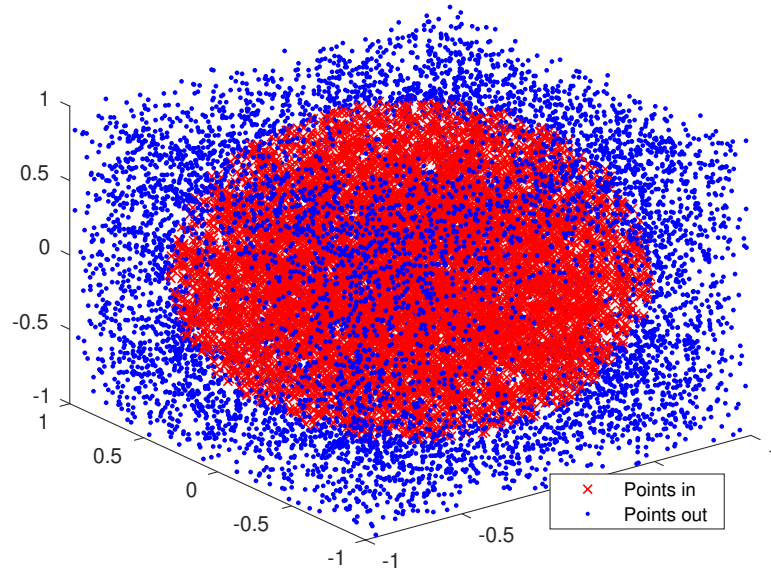
```

```

3.03% Completed, Estimated remaining time 922845.31 minutes6.06% Completed, Estimated remaining
Calculated Pi is 4.50000000 with a Standard Error of 1.50000000 and actual Pi is 3.14159265
Calculated Pi is 3.00000000 with a Standard Error of 1.13389342 and actual Pi is 3.14159265
Calculated Pi is 3.37500000 with a Standard Error of 0.76852131 and actual Pi is 3.14159265
Calculated Pi is 2.62500000 with a Standard Error of 0.53458983 and actual Pi is 3.14159265
Calculated Pi is 3.09375000 with a Standard Error of 0.37777987 and actual Pi is 3.14159265
Calculated Pi is 2.81250000 with a Standard Error of 0.26568651 and actual Pi is 3.14159265
Calculated Pi is 3.02343750 with a Standard Error of 0.18786155 and actual Pi is 3.14159265
Calculated Pi is 3.11718750 with a Standard Error of 0.13261090 and actual Pi is 3.14159265
Calculated Pi is 3.25195312 with a Standard Error of 0.09346444 and actual Pi is 3.14159265
Calculated Pi is 3.07910156 with a Standard Error of 0.06628440 and actual Pi is 3.14159265
Calculated Pi is 3.16406250 with a Standard Error of 0.04681057 and actual Pi is 3.14159265
Calculated Pi is 3.10327148 with a Standard Error of 0.03312801 and actual Pi is 3.14159265
Calculated Pi is 3.11791992 with a Standard Error of 0.02342010 and actual Pi is 3.14159265
Calculated Pi is 3.16387939 with a Standard Error of 0.01654832 and actual Pi is 3.14159265
Calculated Pi is 3.14392090 with a Standard Error of 0.01170535 and actual Pi is 3.14159265
Calculated Pi is 3.12918091 with a Standard Error of 0.00827875 and actual Pi is 3.14159265
Calculated Pi is 3.14797211 with a Standard Error of 0.00585225 and actual Pi is 3.14159265
Calculated Pi is 3.14362335 with a Standard Error of 0.00413846 and actual Pi is 3.14159265
Calculated Pi is 3.14096260 with a Standard Error of 0.00292645 and actual Pi is 3.14159265
Calculated Pi is 3.13827610 with a Standard Error of 0.00206940 and actual Pi is 3.14159265
Calculated Pi is 3.14420271 with a Standard Error of 0.00146315 and actual Pi is 3.14159265
Calculated Pi is 3.14221287 with a Standard Error of 0.00103464 and actual Pi is 3.14159265
Calculated Pi is 3.14153266 with a Standard Error of 0.00073161 and actual Pi is 3.14159265
Calculated Pi is 3.14274859 with a Standard Error of 0.00051731 and actual Pi is 3.14159265
Calculated Pi is 3.14091012 with a Standard Error of 0.00036581 and actual Pi is 3.14159265
Calculated Pi is 3.14160459 with a Standard Error of 0.00025866 and actual Pi is 3.14159265
Calculated Pi is 3.14158351 with a Standard Error of 0.00018290 and actual Pi is 3.14159265
Calculated Pi is 3.14156686 with a Standard Error of 0.00012933 and actual Pi is 3.14159265
Calculated Pi is 3.14160891 with a Standard Error of 0.00009145 and actual Pi is 3.14159265
Calculated Pi is 3.14162934 with a Standard Error of 0.00006467 and actual Pi is 3.14159265
Calculated Pi is 3.14167717 with a Standard Error of 0.00004573 and actual Pi is 3.14159265
Calculated Pi is 3.14162917 with a Standard Error of 0.00003233 and actual Pi is 3.14159265

```

MC simulation data for Pi



Calculated value of Pi and errors

