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% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_07_3_Mehrfreiheitsgradschwinger_3: Schwingungen eines
% Mehrfreiheitsgradschwingers infolge harmonischer Krafterregung (mehrere
% Kräfte und Erregerfrequenzen; Modalanalyse; Massenmatrix und
% Nachgiebigkeitsmatrix)
%
% Version 1.0, April 2018
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedateien:
% Inputdatei_1: Nachgiebigkeitsmatrix [m/N, bzw. 1/Nm]
% Inputdatei_2: Massenmatrix [kg, bzw. kgm²]
% Inputdatei_3: Definition der harmonischen Kräfte
%               Spalte 1: Kraftamplitude [N] bzw. [Nm]
%               Spalte 2: Erregerfrequenz [Hz]
%               Spalte 2: Phasenverschiebung [-]
% Inputdatei_4: Modale Dämpfungsmaße [-]
% ANMERKUNG: Dezimaltrennzeichen '.'
%
% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2: Verschiebungszeitverläufe [m] bzw. [-]

%---------------------------- EINGABEBLOCK --------------------------------
% Einlesen von Eingabedateien und Generierung der entsprechenden Vektoren
% und Matrizen

% Nachgiebigkeitsmatrix
H=dlmread('Inputdatei_1_Nachgiebigkeitsmatrix.txt');

% Massenmatrix
M=dlmread('Inputdatei_2_Massenmatrix.txt');

% Definition der harmonischen Erregerkräfte
Kraftparameter=dlmread('Inputdatei_3_Kraftdefinition.txt');
efampl=Kraftparameter(:,1);  % Erregerkraftamplituden
effreq=Kraftparameter(:,2);  % Erregerkraftfrequenz
efphas=Kraftparameter(:,3);  % Phasenverschiebung der Erregerkraft

% Modale Dämpfungsmaße
xi_mod=dlmread('Inputdatei_4_Modale_Daempfungsmasse.txt');
%--------------------------------------------------------------------------
% Eingaben im Quellcode
t_ber=2.5;          % Berechnungszeit [s]

dt=0.0005;          % Berechnungszeitschritt [s]

n_ef=5;             % Anzahl der bei der Berechnung berücksichtigten
                    % Eigenformen

% Es werden die Schwingungsreaktionen von nur drei ausgewählten
% Freiheitsgraden geplottet. Bitte geben Sie die gewünschten
% Freiheitsgrade an:
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```
plot_1_EF=1;
plot_2_EF=2;
plot_3_EF=3;
%--------------------------------------------------------------------------

%------------------------- BERECHNUNGSBLOCK -----------------------------
n=length(H); % Matrixdimension

% Invertierung der Nachgiebigkeitsmatrix ergibt die Steifigkeitsmatrix
K=H^-1;

% Lösung des Eigenwertproblems: dafür steht in Matlab der vordefinierte
% Befehl "eig" zur Verfügung. Matlab wählt mit diesem Befehl das günstigste
% Lösungsverfahren, sodass das Eigenwertproblem auch in dem Fall einer
% singulären Massenmatrix gelöst werden kann.
[A,EW]=eig(K,M); % A-Eigenformmatrix, EW-Eigenwertmatrix

% Definition eines Vektors für die ermittelten Eigenwerte
D_EW=diag(EW);

% Ermittlung von Eigenkreisfrequenzen
Omega=sqrt(D_EW);

% Sortierung der Eigenwerte in aufsteigender Reihenfolge
[Omega, index]=sortrows(Omega);
A=A(:,index);

% Ermittlung von Eigenfrequenzen
Freq=Omega/(2*pi);

% Ermittlung von Eigenschwingzeiten
T=1./Freq;

% Nachfolgend sind drei Varianten für die Normierung der Eigenvektoren
% vorbereitet. Bitte unkommentieren Sie die gewünschte Variante bzw.
% kommentieren Sie durch Anwendung des Symbols "%" am Anfang jeder Zeile
% die übrigen zwei Abschnitte.

% Normierung der Eigenvektoren auf das betragsgrößte Element
for j=1:1:n
    if max(A(:,j))>abs(min(A(:,j)))
       z1=max(A(:,j));
       for i=1:1:n
         A(i,j)=(A(i,j)/z1);
       end
    else
       z1=min(A(:,j));
       for i=1:1:n
         A(i,j)=(A(i,j)/z1);
       end
    end
end

% Normierung der Eigenvektoren bezüglich der generalisierten Masse
% for j=1:1:n
%     z2=(A(:,j))'*M*(A(:,j));
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```
%         for i=1:1:n
%           A(i,j)=(A(i,j)/sqrt(z2));
%         end
% end


% % Normierung der Eigenvektoren (Wurzel-Ansatz)
% z3=zeros(n,1);
% z4=zeros(n,1);
% for j=1:1:n
%     for i=1:1:n
%         z3(j)=z3(j)+(A(i,j))^2;
%     end
%     z4(j)=sqrt(z3(j));
% end
%
% for j=1:1:n
%     for i=1:1:n
%         A(i,j)=A(i,j)/z4(j);
%     end
% end

% Berechnung der modalen Steifigkeitsmatrix
K_mod=A'*K*A;

% Berechnung der modalen Massenmatrix
M_mod=A'*M*A;

% Berechnungsparameter
T_positive=T(T(:,1)>0,:);
nt=ceil(t_ber/dt)+1;      % Anzahl Berechnungszeitschritte
t_b=0:dt:dt*(nt-1);       % Zeitvektor für die Berechnung

% Vergrößerungsfunktion an den Stellen der Erregerfrequenzen
V=zeros(n,1);
for i=1:1:n
    for j=1:1:n
        V(i,j)=1/(sqrt((1-((effreq(i)*2*pi)/Omega(j))^2)^2+...
            (2*xi_mod(j)*((effreq(i)*2*pi)/Omega(j)))^2));
    end
end

% Phasenverschiebung an den Stellen der Erregerfrequenzen
phi=zeros(n,1);
for i=1:1:n
    for j=1:1:n
        phi(i,j)=atan((2*xi_mod(j)*((effreq(i)*2*pi)/Omega(j)))/...
             (1-((effreq(i)*2*pi)/Omega(j))^2));
    end
end

% Berechnung der Schwingungsreaktion
ita_y=zeros(n,nt);   % Normalisierte Koordinaten
ita_h=zeros(1,n);
for k=1:1:nt
    for j=1:1:n
        for i=1:1:n
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        ita_h(i)=((A(i,j)*efampl(i))/K_mod(j,j))*V(i,j)*sin(effreq(i)*...
            2*pi*t_b(k)+efphas(i)-phi(i,j));
        ita_y(j,k)=ita_y(j,k)+ita_h(i);
        end
    end
end

% Überlagerung der Schwingungsreaktionen der berücksichtigten Eigenformen
% für alle Freiheitsgrade
y=A(:,1:n_ef)*ita_y(1:n_ef,:);

% Maximaler Schwingweg von allen Freiheitsgraden
ymax=zeros(n,1);
for i=1:1:n
    ymax(i)=max(abs(y(i,:)));
end
%--------------------------------------------------------------------------

%------------------------ DARSTELLUNGSBLOCK ------------------------------
% Grafische Darstellung der Ergebnisse
name_fig1 = 'Schwingungsantworten';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[200 300 800 500]);

subplot(3,1,1)
plot(t_b,y(plot_1_EF,:),'MarkerSize',3);
title1 = [num2str(plot_1_EF),'. Freiheitsgrad'];
title(title1);
xlabel('Zeit [s]');
ylabel('Verschiebung [m] bzw. [-]');
grid on; zoom on;

subplot(3,1,2)
plot(t_b,y(plot_2_EF,:),'MarkerSize',3);
title2 = [num2str(plot_2_EF),'. Freiheitsgrad'];
title(title2);
xlabel('Zeit [s]');
ylabel('Verschiebung [m] bzw. [-]');
grid on; zoom on;

subplot(3,1,3)
plot(t_b,y(plot_3_EF,:),'MarkerSize',3);
title3 = [num2str(plot_3_EF),'. Freiheitsgrad'];
title(title3);
xlabel('Zeit [s]');
ylabel('Verschiebung [m] bzw. [-]');
grid on; zoom on;

%--------------------------------------------------------------------------

%---------------------------- AUSGABEBLOCK --------------------------------
% Ausgabe der Ergebnisse in eine Datei
EF=[Omega Freq T];
fid = fopen('Outputdatei_1_Allgemein.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
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    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_07_3: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Berechnungszeit [s]:');
fprintf(fid,'%.2f\n',t_ber);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Berechnungszeitschritt [s]:');
fprintf(fid,'%d\n',dt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der beruecksichtigen Eigenformen [-]:');
fprintf(fid,'%d\n',n_ef);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftdefinition:');
fprintf(fid,'%s \t %s \t %s \t %s \n','Freiheitsgrad [-]',...
    'Kraftamplitude [N]', 'Erregerfrequenz [Hz]',...
    'Phasenverschiebung [-]');
for jj=1:1:n
    fprintf(fid,'%d \t %d \t %d \t %d\n',jj,efampl(jj),effreq(jj),...
        efphas(jj));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Format= "%d \t ";
if n>2
    for ii=1:1:n-2
        Format=Format + '%d \t ';
    end
end
Format=Format + '%d\n';
fprintf(fid,'%s\n','Nachgiebigkeitsmatrix [m/N] bzw. [1/Nm]');
for jj = 1:1:n
     fprintf(fid, Format, H(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Massenmatrix in [kg] bzw. [kgm^2]');
for jj = 1:1:n
     fprintf(fid, Format, M(jj,:));
 end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Modale Daempfungsmasse [-]');
for jj = 1:1:n
    Name=[num2str(jj) '.te Eigenform:'];
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    fprintf(fid, '%s \t %d\n', Name, xi_mod(jj));
 end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der Freiheitsgrade:');
fprintf(fid,'%d\n',n);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der Berechnungszeitschritte:');
fprintf(fid,'%d\n',nt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Steifigkeitsmatrix in [N/m] bzw. [Nm]');
for jj = 1:1:n
     fprintf(fid, Format, K(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s \t %s \t %s\n','Eigenkreisfrequenzen [1/s]',...
    'Eigenfrequenzen [Hz]','Eigenschwingzeiten [s]');
for jj = 1:1:n
     fprintf(fid, '%d \t %d \t %d\n', EF(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Normierte Eigenformmatrix [-]');
for jj = 1:1:n
     fprintf(fid, Format, A(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Modale Steifigkeitsmatrix in [N/m] bzw. [Nm]');
for jj = 1:1:n
     fprintf(fid, Format, K_mod(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Modale Massenmatrix in [kg] bzw. [kgm^2]');
for jj = 1:1:n
     fprintf(fid, Format, M_mod(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Verschiebungen der Freiheitsgrade [m]:');
for jj = 1:1:n
     Name=[num2str(jj) '.ter FG'];
     fprintf(fid, '%s \t %d\n', Name, ymax(jj,:));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
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```
fprintf(fid,...
    '%s\n','----------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Verschiebungen=[t_b' y'];
fid = fopen('Outputdatei_2_Verschiebungen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_07_3: Verschiebungszeitverlaeufe');
fprintf(fid, '%s\n', ' ');

Format_Header= "%s \t ";
if n>1
    for ii=1:1:n-1
        Format_Header=Format_Header + '%s \t ';
    end
end
Format_Header=Format_Header + '%s\n ';

Header=strings(1,n+1);
Header(1)='Zeit [s]';
for iii=1:1:n
    Header(iii+1)=strcat('Verschiebung ', {' '}, num2str(iii),...
        '. FG [m], [-]');
end
fprintf(fid,Format_Header,Header);
Format= "%d \t ";
if n>1
    for ii=1:1:n-1
        Format=Format + '%d \t ';
    end
end
Format=Format + '%d\n';
for jj = 1:1:length(Ergebnis_Verschiebungen)
    fprintf(fid, Format, Ergebnis_Verschiebungen(jj,:));
end
fclose(fid);
%--------------------------------------------------------------------------
```