```
% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_20_1_Zugueberfahrt_Einfeldtraeger: Zugüberfahrt über einen
% Einfeldträger
%
% Version 1.0, April 2018
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedateien:
% Inputdatei_1: Lastdefinition
%               - Spalte 1: Örtliche Koordinate der Last mit Bezug auf die
%                 erste Achse [m]
%               - Spalte 2: Achslasten [kN]
% ANMERKUNG: Dezimaltrennzeichen '.'

% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2: Zeitverläufe der Bewegungsgrößen an dem Ausgabepunkt:
%                Verschiebung [m], Geschwindigkeit [m/s] und
%                Beschleunigung [m/s^2]

%---------------------------- EINGABEBLOCK --------------------------------
% Einlesen von Eingabedateien und Generierung der entsprechenden Vektoren
% und Matrizen
Kraftdefinition=dlmread('Inputdatei_1.txt');
% Koordinaten der Radsätze mit Bezug auf den ersten Radsatz [m]
x_k=Kraftdefinition(:,1);
% Achslasten in [N]
P_k=Kraftdefinition(:,2);
%--------------------------------------------------------------------------
% Eingaben im Quellcode

% Strukturdefinition
l=16.4;                         % Trägerlänge [m]
mue=5063;                       % Masse pro Längeneinheit [kg/m]
xi=0.0257;                      % Dämpfungsmaß [-]
I=0.0288;                       % Flächenträgheitsmoment [m^4]
E=2.1*10^11;                    % Elastizitätsmodul [N/m^2]

% Berechnungsparameter
a_tmax=1.5;                     % Faktor, der die Gesamtzeit der Berechnung
                                % steuert. Für a_tmax=1 ist die
                                % Berechnungsdauer gleich der
                                % Überquerungszeit des Trägers.

ndt=20;                         % Anzahl der Unterteilungen der kleinsten
                                % Eigenschwingzeit zwecks Definition eines
                                % geeigneten Berechnungszeitschritts

x0=6.6;                         % Stelle der Ausgabe [m]

n=3;                            % Anzahl der berücksichtigten Eigenformen

v_zug_kmh=161.2;                % Zuggeschwindigkeit in [km/h]
```

```
%--------------------------------------------------------------------------

%------------------------- BERECHNUNGSBLOCK -----------------------------
% Berechnung weiterer System- und Berechnungsparameter
Freq=zeros(n,1);        % Eigenfrequenzen
Omega=zeros(n,1);       % Eigenkreisfrequenzen
T=zeros(n,1);           % Eigenschwingzeiten

for i=1:1:n
    Freq(i)=((i*pi)^2/(2*pi*l^2))*sqrt(E*I/mue);
    Omega(i)=2*pi*Freq(i);
    T(i)=1/Freq(i);
end

m=zeros(n,1);        % Vektor der modalen Massen
k=zeros(n,1);        % Vektor der modalen Steifigkeiten
d=zeros(n,1);        % Vektor der modalen Dämpferkonstanten

for i=1:1:n
   m(i)=0.5*mue*l;
   k(i)=Omega(i)^2*m(i);
   d(i)=2*xi*sqrt(k(i)*m(i));
end

v_zug=v_zug_kmh*1000/3600;   % Zuggeschwindigkeit in [m/s]
dt=min(T)/ndt;               % Berechnungszeitschritt
l_zug=max(x_k);              % Zuglänge
T_u=(l+l_zug)/(v_zug);       % Zeit zur Überquerung des Trägers
t_ber=T_u*a_tmax;            % Dauer der Berechnung
nt=ceil(t_ber/dt)+1;         % Anzahl der Zeitschritte

% Erstellung des Zeitvektors
t=0:dt:dt*(nt-1);

% Eigenformen am Ausgabepunkt
phi_a=zeros(n,1);
for i=1:1:n
    phi_a(i)=sin(i*pi*x0/l);
end

% Kraftdefinition für die Berechnung

% Matrix zur Berücksichtigung der sich auf der Brücke befindenden Lasten
% in jedem Zeitschritt
F_Mat=zeros(length(x_k),nt);
for i=1:1:nt
    for j=1:1:length(x_k)
        if (-x_k(j)+v_zug*t(i))>0 && (-x_k(j)+v_zug*t(i))<l
            F_Mat(j,i)=P_k(j);
        else
            F_Mat(j,i)=0;
        end
    end
end

% Erstellung der Matrix der generalisierten Lasten
```

```
Gen_K=zeros(n,nt);
for u=1:1:n
    for i=1:1:nt
        for j=1:1:length(x_k)
            Gen_K(u,i)=Gen_K(u,i)+F_Mat(j,i)*...
                sin(u*(-x_k(j)+v_zug*t(i))*pi/l);
        end
    end
end

% Berechnung der Schwingungsantwort mittels Newmark-Verfahren

% Integrationsparameter
alpha=0.5;
beta=0.25;

% Berechnungsvorschrift
ita_y=zeros(n,length(t));
ita_v=zeros(n,length(t));
ita_a=zeros(n,length(t));
for j=1:1:n
    for i=2:1:length(t)
        a_h=((1/beta)*m(j))+(alpha/beta)*d(j)*dt+k(j)*dt^2;
        b_h=((1/beta)*m(j)+(alpha/beta)*d(j)*dt)*ita_y(j,i-1)+...
            ((1/beta)*m(j)+(alpha/beta-1)*d(j)*dt)*dt*ita_v(j,i-1)+...
            ((1/(2*beta)-1)*m(j)+(alpha/(2*beta)-1)*d(j)*dt)*dt^2*...
            ita_a(j,i-1)+Gen_K(j,i)*dt^2;
        ita_y(j,i)=a_h^-1*b_h;
        ita_v(j,i)=(alpha/(beta*dt))*(ita_y(j,i)-ita_y(j,i-1))-...
            ((alpha/beta)-1)*ita_v(j,i-1)-(alpha/(2*beta)-1)*dt*...
            ita_a(j,i-1);
        ita_a(j,i)=(1/(beta*dt^2))*(ita_y(j,i)-ita_y(j,i-1))-...
            1/(beta*dt)*ita_v(j,i-1)-(1/(2*beta)-1)*ita_a(j,i-1);
    end
end

% Überlagerung aller Eigenformen
y=zeros(1,length(t));     % Vektor der Gesamtverschiebung
v=zeros(1,length(t));     % Vektor der Gesamtgeschwindigkeit
a=zeros(1,length(t));     % Vektor der Gesamtbeschleunigung

for j=1:1:n
    for i=1:1:length(t)
        y_tot_h=phi_a(j)*ita_y(j,i);
        y(i)=y(i)+y_tot_h;
        v_tot_h=phi_a(j)*ita_v(j,i);
        v(i)=v(i)+v_tot_h;
        a_tot_h=phi_a(j)*ita_a(j,i);
        a(i)=a(i)+a_tot_h;
    end
end

% Extremwerte
ymax=max(y);   ymin=min(y);
vmax=max(v);   vmin=min(v);
amax=max(a);   amin=min(a);
%--------------------------------------------------------------------------
```

```
%------------------------ DARSTELLUNGSBLOCK -----------------------------
% Grafische Darstellung der Ergebnisse
name_fig1 = 'Zeitverläufe';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[1000 50 700 900]);

subplot(4,1,1)
stem(x_k,P_k,'r','MarkerSize', 0.5);
title('Lastbild');
xlabel('Koordinate [m]');
ylabel('Kraft [N]');
grid on;

subplot(4,1,2)
plot(t,y,'b','LineWidth', 1);
title('Verschiebungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Verschiebung [m]');
grid on;

subplot(4,1,3)
plot(t,v,'b','LineWidth', 1);
title('Geschwindigkeitszeitverlauf');
xlabel('Zeit [s]');
ylabel('Geschwindigkeit [m/s]');
grid on;

subplot(4,1,4)
plot(t,a,'b','LineWidth', 1);
title('Beschleunigungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
grid on;
%-------------------------------------------------------------------------

%---------------------------- AUSGABEBLOCK -------------------------------
% Ausgabe der Ergebnisse in eine Datei
fid = fopen('Outputdatei_1_Allgemein.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_20_1: 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','Traegerlaenge [m]:');
```

```
fprintf(fid,'%d\n',l);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Masse pro Laengeneinheit [kg/m]:');
fprintf(fid,'%d\n',mue);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungsmass [-]:');
fprintf(fid,'%d\n',xi);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Flaechentraegheitsmoment [m^4]:');
fprintf(fid,'%d\n',I);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Elasitizitätsmodul [N/m^2]:');
fprintf(fid,'%d\n',E);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Lastbild: s. Dateiende');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Faktor fuer die Berechnungsdauer [-]:');
fprintf(fid,'%.3f\n',a_tmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl Unterteilungen der kleinsten Eigenschwingzeit');
fprintf(fid,'%.3f\n',ndt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anzahl der berücksichtigten Eigenformen');
fprintf(fid,'%.3f\n',n);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Stelle der Ausgabe [m]:');
fprintf(fid,'%.3f\n',x0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Ueberfahrtgeschwindigkeit in [km/h]:');
fprintf(fid,'%d\n',v_zug_kmh);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
EF=[Omega Freq T];
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', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
Modal=[m k d];
fprintf(fid,'%s \t %s \t %s \t %s\n','EF','Modale Masse [kg]',...
    'Modale Steifigkeit [N/m]','Modale Daempfung [Ns/m]');
for jj = 1:1:n
     fprintf(fid, '%d \t %d \t %d \t %d\n',jj,Modal(jj,:));
end
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 Berechnungszeitschritte [-]:');
fprintf(fid,'%d\n',nt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Gesamtdauer der Berechnung [s]:');
fprintf(fid,'%d\n',t_ber);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Ueberfahrtgeschwindigkeit in [m/s]:');
fprintf(fid,'%d\n',v_zug);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Zuglaenge [m]:');
fprintf(fid,'%d\n',l_zug);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Zeit zur Ueberquerung des Traegers [s]:');
fprintf(fid,'%d\n',T_u);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Eigenformen am Ausgabepunkt [-]:');
fprintf(fid,'%s \t %s\n','EF','Wert der Eigenform [-]:');
for jj=1:1:length(phi_a)
    fprintf(fid,'%d \t %d\n',jj,phi_a(jj));
end
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Integrationsparameter fuer das Newmark-Verfahren:');
fprintf(fid,'%s \t %.4f\n','alpha=',alpha);
fprintf(fid,'%s \t %.4f\n','beta=',beta);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Verschiebung [m]:');
fprintf(fid,'%d\n',ymax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Verschiebung [m]:');
fprintf(fid,'%d\n',ymin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmin);
```

```
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Lastbild:');
fprintf(fid,'%s \t %s\n','Koordinate [m]','Radsatzlast [N]');
for jj=1:1:length(x_k)
    fprintf(fid,'%d \t %d\n',x_k(jj), P_k(jj));
end
fprintf(fid, '%s\n', ' ');
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Bewegungsgroessen=[t' y' v' a'];
fid = fopen('Outputdatei_2_Bewegungsgroessen.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 %s\n','Programm ML_20_1: Zeitverlaeufe der',...
    'Bewegungsgroessen am Ausgabepunkt');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Zeitverlaufe der Bewegungsgroessen ');
fprintf(fid,'%s \t %s \t %s \t %s\n','Zeit [s]:',...
    'Verschiebung [m]', 'Geschwindigkeit [m/s]',...
    'Beschleunigung [m/s^2]');
for ii=1:1:length(y)
    fprintf(fid, '%d \t %d \t %d \t %d\n',...
        Ergebnis_Bewegungsgroessen(ii,:));
end
fclose(fid);
%--------------------------------------------------------------------------
```