**Model 1: Systemic Arteries**

**Model can be found:** <https://classroom.github.com/a/Oy_UDNtp>

**Model requires:** sa.m, in\_sa.m, QAo\_now.m, Psa\_new.m

**Instructions:** To complete this assignment you must do 2 things.

1. Answer the questions below in a Word document.
2. Generate plots/measurements to demonstrate your findings.
3. How to track/commit your code.
   1. Clone the repository from the Github classroom.
   2. For each commit make sure to commit both changes to the provided code as well as any new files/scripts you generate. Also add figures associated with your findings to the repo.

**Section 1: Understanding the provided code**

Task 1: Describe the following files

* QAo\_now.m: Overview and line by line

function Q=QAo\_now(t)

%filename: QAo\_now.m

global T TS TMAX QMAX; %get variables from other scrips

tc=rem(t,T); % tc=time elapsed since

%the beginning of the current cycle

%rem(t,T) is the remainder when t is divided by T

if(tc<TS) % At the time when time elapsed is smaller than systole

%SYSTOLE:

if(tc<TMAX) % At the time when time elapsed is smaller than TMAX

%BEFORE TIME OF MAXIMUM FLOW:

Q=QMAX\*tc/TMAX; % Flow with respect to tc when tc is less than TMAX

else

%AFTER TIME OF PEAK FLOW:

Q=QMAX\*(TS-tc)/(TS-TMAX);% Flow with respect to tc when tc is more than TMAX

end

else

%DIASTOLE:

Q=0; % is time elapses is smaller then systole, flow is 0

end

* Psa\_new.m: Overview and line by line

function Psa=Psa\_new(Psa\_old,QAo)

%filename: Psa\_new.m

global Rs Csa dt; %Get parsmeters from other file

Psa=(Psa\_old+dt\*QAo/Csa)/(1+dt/(Rs\*Csa)); %function of the pressure of systemic arterial

* sa.m: Overview and lines 4-15

%filename: sa.m

clear all % clear all variables

clf % and figures

global T TS TMAX QMAX; %get variables from other scrips

global Rs Csa dt; %get variables from other scrips

in\_sa %initialization

Csa=Csa/2

for klok=1:klokmax

t=klok\*dt; %at each unit of time

QAo=QAo\_now(t);%flow of arterial (opening)

Psa=Psa\_new(Psa,QAo); %new Psa overwrites old

%Store values in arrays for future plotting:

t\_plot(klok)=t; %building array for time

QAo\_plot(klok)=QAo;%building array for flow of arterial (opening)

Psa\_plot(klok)=Psa;%building array for pressure of systemic arterial

end

%Now plot results in one figure

%with QAo(t) in upper frame

% and Psa(t) in lower frame

subplot(2,1,1), plot(t\_plot,QAo\_plot) %plot the graph of t vs QAo

subplot(2,1,2), plot(t\_plot,Psa\_plot) %plot the graph of t vs Psa

Task 2: Adjust Csa to achieve a blood pressure of 120/80 (+/- 1 mmHg is ok). For your value, state what the error you see is in systolic and diastolic pressure.

When Csa is 0.00215. The blood pressure is 80.0482/120.7937.

The error is 0.0482 mmHg and 0.7937 mmHg respectively.

Task 3: Check that the time step is small enough. For a range of delta t’s, calculate the error you see in Psa(t). At what delta t value is the error < 1%.?

For timestep from 0.0000 to 0.001 with each step size of 0.0002. The errors are 5.7677%, 1.0872%, 0.41%, 0.31% and 0.29%. So that we could see that at time step larger than 0.0005, the dt value is smaller than 1%.

Task 4: Vary initial pressure parameter Psa and describe impact on the simulation results

The final error and Psa value will not change if time step is larger, no matter how we modify the initial pressure parameter Psa. The smaller the step size, the more Psa varies from the actual value.

Task 5: Evaluate how many beats are necessary to achieve steady state. What level of similarity and what measures are you using to consider the model in steady-state? Specifically, what numerical measure do you propose to use to estimate that the model has reached steady state?

By calculation, I have found that around 6 beats, it will reach steady state. The standard of stable state is calculated as following: the next peak value is <=1% difference of previous peak value.

%filename: sa.m

clear all % clear all variables

clf % and figures

global T TS TMAX QMAX; %get variables from other scrips

global Rs Csa changeindt dt; %get variables from other scrips

in\_sa; %initialization

Csa=Csa/2;

changeindt=0.0000:0.0001:0.001;

errorarray=[];

for i=1:11

dt=changeindt(i)\*T

for klok=1:klokmax

t=klok\*dt; %at each unit of time

QAo=QAo\_now(t);%flow of arterial (opening)

Psa=Psa\_new(Psa,QAo); %new Psa overwrites old

%Store values in arrays for future plotting:

t\_plot(klok)=t; %building array for time

QAo\_plot(klok)=QAo;%building array for flow of arterial (opening)

Psa\_plot(klok)=Psa;%building array for pressure of systemic arterial

end

%Now plot results in one figure

%with QAo(t) in upper frame

% and Psa(t) in lower frame

larger=max(Psa\_plot); %find the global maximum

pks=findpeaks(Psa\_plot) % find the local maxima

error=100\*(abs(80-Psa))/80; %find error in %

subplot(2,1,1), plot(t\_plot,QAo\_plot) %plot the graph of t vs QAo

subplot(2,1,2), plot(t\_plot,Psa\_plot) %plot the graph of t vs Psa

errorarray=[errorarray error];% sort into an array

end

errorarray %display error array in %

last=pks(end); %find the last local maxima of the Psa

for j=1:length(pks) %loop the number of peaks

if abs(pks(j)-last)/last <= 0.01 % if next peak value is smaller than 1% variation of previous value

stable\_state=pks(j); %choose that value as stable state

break

else

continue

end

end

display(stable\_state);

number\_of\_itrations = find(pks==stable\_state); %locate the number of beats

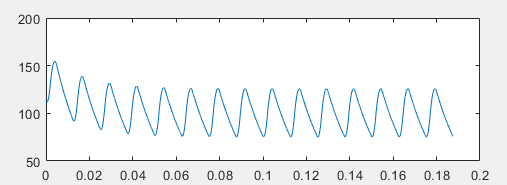
time\_to\_stable=(T+TS)\*number\_of\_itrations; %find the time (minutes)

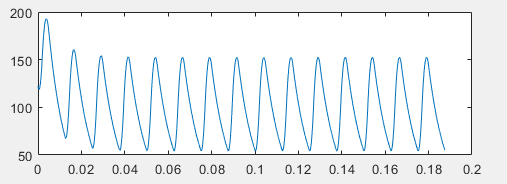
display(time\_to\_stable)

**Section 2: Exploring the aging process**

Task 6: Reduce systemic arterial compliance by factor of 2. Describe the impact on your model. Specifically, what happens to the pressure waveform and systolic, diastolic and mean pressure values? Physiologically, what does decreasing arterial compliance represent? Why does it mimic aging?

The model shows higher variation between systolic and diastolic pressure. The mean pressure is not changing.





The increase in pulse pressure with aging is mainly due to a decrease in large artery compliance. This physically means that blood vessels with a higher compliance deform easier than lower compliance blood vessels under the same pressure and volume conditions.

**Section 3: Exploring exercise**

Task 7: Decrease the systemic resistance by factor of 2. What must you do to the heart rate to maintain blood pressure? If you only change heart rate, what happens to stroke volume?

As I decrease the systemic resistance by factor of 2, the mean pressure is decreased. In order to maintain blood pressure, the heart must pump faster to provide enough blood for body use.

If I only change heart rate, the stroke volume will decrease.

Task 8: What must you do to Qmax to maintain appropriate stroke volume?

In order to maintain appropriate stroke volume, Qmax needs to be decreased.

Task 9: If a patient is unable to change their heart rate (and can only increase cardiac output via stroke volume) and exercises (decreasing systemic resistance by factor of 2), what is the impact on pressure?

The pressure will increase.

**Section 4: Anxiety**

Task 10: If you decrease systemic resistance by factor of 2 without changing the heart rate or Qmax, what is the impact on the persons pressures?

The systolic, diastolic and mean pressure will all be decreased.

**Section 5: Cardiac Arrest**

Task 11: Add two variables t\_arrest and t\_restart that cause cardiac output to be 0 between those times (result of QAo\_now(t) = 0 if t > t\_arrest and t < t\_restart). What is the impact on the systemic pressures for different durations of arrest.

The systemic pressure during arrest tends to converge to zero.



(Arrest from time 0.01 to 0.05)

Commit your code with your changes to GitHub

Task 12: Consider irreversible damage to occur if systolic pressures < 50 mmHg. What period of arrest can a person maintain without this irreversible damage?

From previous graph, we could see that during 0 to 0.02, the systolic pressure is >50 mmHg. So that during 0 to 0.02 time, the person could maintain without irreversible damage.

Task 13: Does aging improve or exacerbate the findings in Task 12?

By setting systemic arterial compliance by half, we could mimic the aging effect.



From the graph, we could see that the time is between 0 to around 0.015. Such range is smaller than the time range of a young patient. So that aging will exacerbate the findings in Task 12.

Task 14: What if arrest occurs during exercise? Is it better or worse than findings in Task 12?

By setting systemic resistance by half, we could mimic the exercise scenario.



From the graph, we could see that the time for maintaining before <50 mmHg is smaller than that in task 12. The range is around 0 to 0.01. So that exercise will exacerbate the situation.