MXB103 Project Group 69: BUNGEE!

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1 Introduction

In terms of Brisbane's "New world city" plan, Brisbane city council has suggested a proposal that bungee jumping off is set on the bridge, Story Bridge. This report provides several key questions as solutions on the proposal for the council.

With the following section 2 on this report, the proposal and the important questions are discussed in terms of the proposal in detail. In section 3, 4, and etc.

2 The proposal

A platform is called for as the proposal in order to be installed at the very top of Story Bridge.

For the first of all, either a second order or higher numerical method is implemented in order to model the bungee jump. The codes that we have written involve the numerical solution for the model. What is more, the position of the bungee jumper is plotted according to time.

The second is that the observation of the results of our model and the determination if it agrees with the suggestion that the bungee jump company provides, which is that a standard jump consists of 10 bounces taking 60 seconds, approximately.

The third is that the maximum speed of the bungee jumper is provided as well as when it occurs in relation to the overall jump. Graphically, plotting the velocity of the jumper is shown against time.

The fourth is to solve the following question. To solve them, numerical differentiation must be employed to find the acceleration expected by our model. Moreover, the acceleration of the jumper is graphically plotted against time.

The fifth is to calculating the integral in order to determine how far the jumper specifically travels in the 60 second jump. Also, the jumper's acceleration is plotted against time, graphically.

The sixth is to set a camera on the bridge deck at the height of D from the surface of water. An accurate value for t needs to be computed such as y(t) = H - D.

The last is that we are asked by the bungee jump company to determine how close the jumper touches the surface of the water. How the bungee's rope producing accurately the experience of the water touch for the jumper changes is investigated with 10 bounces in 60 seconds.

These questions that are asked will be answered in order according to each question. These answers will be accurate. This approach will work well as it ensures that the questions are answered accordingly.

The next section will discuss the model in more detail, relating to the equation and its origin.

3 The model

For bungee jumping, the equation of motion is

$$\frac{dv}{dt} = g - C|v|v - max(0, K(y - L))$$

Recognizing the forces (gravity (mg), drag(-c|v|v) and tension (-max(0,k(y-L))) that regularly act on the jumper, the mathematical model of performing bungee jumping can be derived.

The sum of the forces that act on the jumper equals the product of the mass of the jumper and the acceleration of it. The ODE related to bungee jumping is

$$\frac{m}{dv}dt = mg - c|v|v - max(0, k(y - L))$$

The drag force acts in the opposite direction to the motion which always slows the jumper down. The value is given by -c|v|v, c is the drag coefficient and the velocity of the jumper is v. The length of the unstretched rope is L, the tension when the rope is pulled tightly is k(y-L), where the "spring constant" k measures the bungee ropes elasticity. The tension force is - max(0,k(y-L)). When y > L the maximum function makes sure that the tension "switches on". And to make sure that it acts upwards the minus sign is placed in front.

The equation of motion however, is a simplified version by dividing through m. Where C = c/m and K = k/m.

3.1 Assumptions and limitations

There are a few assumptions and limitations of the given model written in this project. First of all, it is assumed that it is valid that the parameters of the model of the factors of the bridge are given by the bungee jump company. Secondly, it is assumed for the Story Bridge that the point in which jumping platform is set up is capable of sustaining the weight of platform and staffs on it. In terms of limitations of the given model, the only case of 80 kilograms jumper is considered as the result generated from the model. What is more, there is a possibility that the expected result generated by the model is different from the actual outcome of the jumping as the given model is a numerical solution.

There exist some limitations in these solutions after the case study conducted. First of all, this investigation ignores the case of rising tide. Therefore, the occurrence of 'water touch' would not exist in reality for a certain time. Moreover, this analysis ignores the case of ships moving under the bridge. Hence it is expected that the safety of the bungee jump is significantly low. On top of that, due to the weight of jumper and variables such as drag coefficient will not always be the same as given parameters, the actual situation of jumping may be variable according to the current situation.

3.2 Parameters

```
H = 74;                 % Height of jump point (m)
D = 31;                 % Deck height (m)
c = 0.9;                % Drag coefficient (kg/m)
m = 80;                 % Mass of the jumper (kg)
L = 25;                 % Length of bungee cord (m)
k = 90;                 % Spring constant of bungee cord (N/m)
g = 9.8;                % Gravitational acceleration (m/s^2)
C = c/m;                % Scaled drag coefficient
K = k/m;                % Scaled spring constant
```

4 The numerical method

Solving the bungee jumping equation will require just a slight modification of numerical methods for solving ODEs that we have developed in our lectures. Because the equation of motion for bungee jumping involves two unknowns, v and y, a second equation is needed to relate the the two. The relationship is quite simple such that the jumper's velocity v is the derivative of the jumpers position y. This problem can be considered as two ODEs.

$$\frac{dy}{dt} = v$$

$$\frac{dv}{dt} = g - C|v|v - max(0, K(y - L))$$

Any numerical method can now be applied to these two equations.

4.1 Parameters

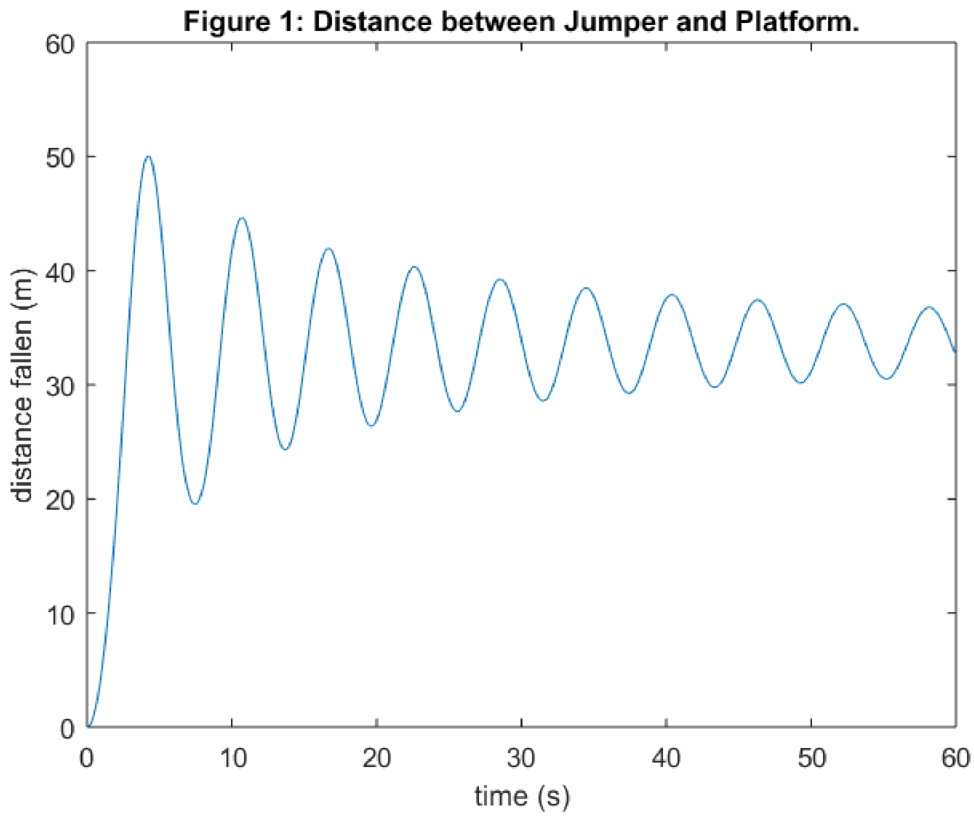
```
T = 60;                 % Final time in simulation (s)
n = 10000;              % Number of subintervals (you decide how many you
 need)
```

4.2 Solution

The ordinary differential equations are solved using the Classical Fourth Order Runge-Kutta method.

```
[t, y, v, h] = rk4_bungee(T, n, g, C, K, L);

figure
plot(t, y);
xlabel('time (s)');
ylabel('distance fallen (m)');
title('Figure 1: Distance between Jumper and Platform.');
```



5 Analysis

In this section, the model predictions are analysed with respect to the key questions being asked about the proposal.

5.1 Timing and bounces

The bungee jump company suggests that the standard jump will consist of 10 "bounces" which should take approximately 60 seconds. Our model, Figure 1, does agree with the timing.

5.2 Maximum speed experienced by the jumper

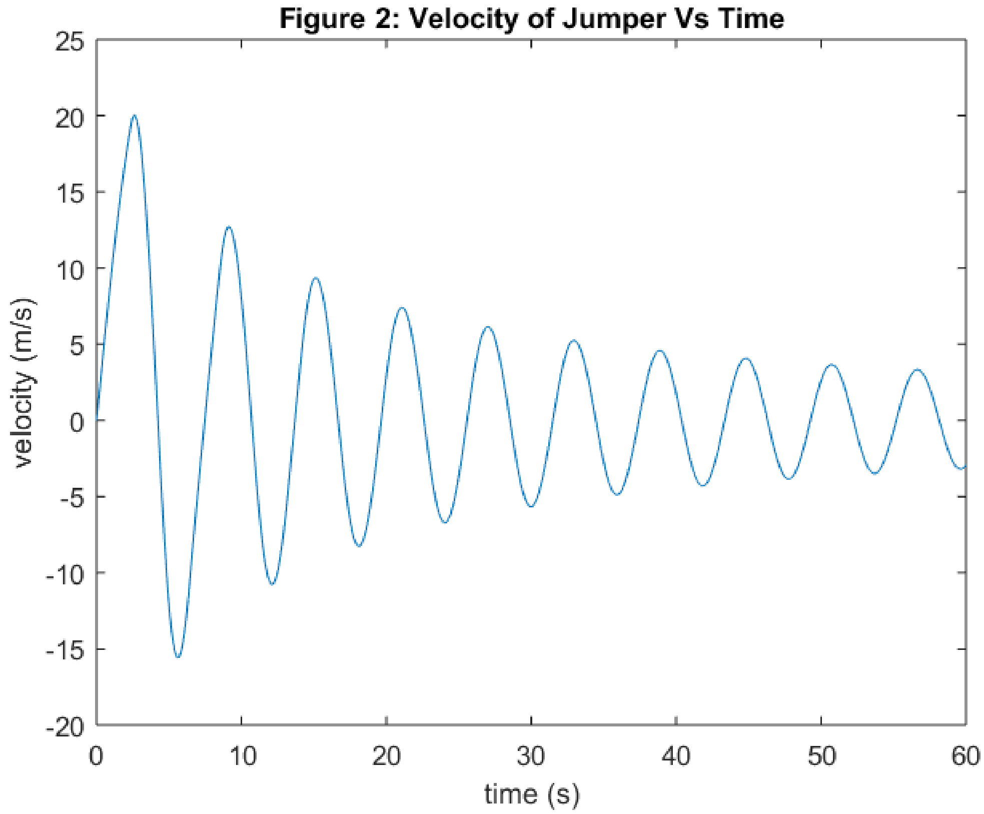
The "thrill factor" of bungee jumping is partly determined by the maximum speed experienced by the jumper.

We can find the maximum velocity by:

```
[t, y, v, h] = rk4_bungee(T, n, g, C, K, L);

figure
plot(t,v);
xlabel('time (s)');
ylabel('velocity (m/s)');
title('Figure 2: Velocity of Jumper Vs Time');
```

```
% According to the graph, it seems that the maximum velocity achieved
 by
% the jumper is approximately 20 m/s.
```



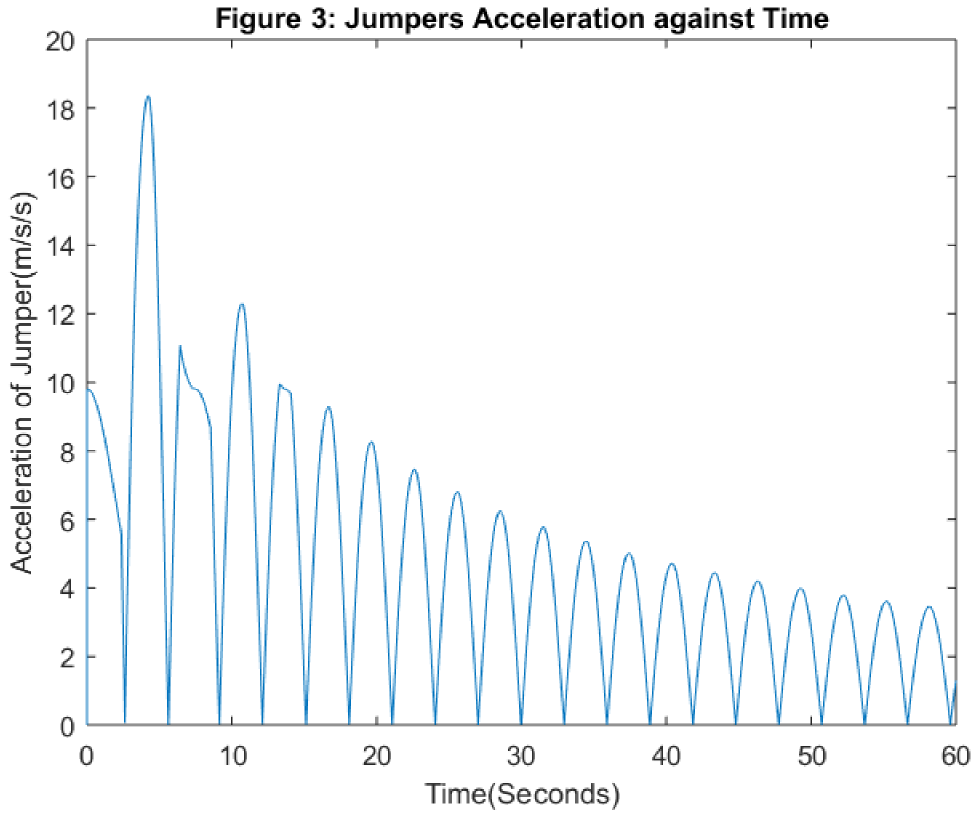
5.3 Maximum acceleration experienced by the jumper

Another factor for thrill-seekers is the maximum acceleration experienced by the jumper. More acceleration equals bigger thrills, however too much acceleration may be dangerous. Using numerical differentiation, the acceleration can be predicted by it.

Therefore the maximum accleration can be determined by

```
[a, ~] = maximum_acceleration_bungee(v,h,n);

figure
plot(t,abs(a));
xlabel('Time(Seconds)');
ylabel('Acceleration of Jumper(m/s/s)');
title('Figure 3: Jumpers Acceleration against Time');
```



According to the graph, the maximum acceleration experienced by the jumper occurs at approximately 4 seconds. Also, the jumper will be able to experience a maximum accleration of 18.3366m/s/s. What is more, the claim of "up to 2g" acceleration is not supported by the model.

5.4 Distance travelled by the jumper

It is of interest to know how far the jumper actually travels in the 60 second jump. Using numerical integration, the answer to this question can be computed to determine how far the jumper travels.

Therefore the distance travelled by the jumper is determined by

```
[t, y, ~, ~, x] = rk_bungee_integral(T, n, g, C, K, L);

figure
plot(t,x);
xlabel('Time(s)');
ylabel('Distance(m)');
title('Figure 4: Distance of jumper travelled');
```

```
Undefined function or variable 'k3'.

Error in rk_bungee_integral (line 40)
       y(i+1) = y(i) + (1/6)*(k_1 + 2*k_2 + 2*k3 + k_4);

Error in MXB103Group69 (line 207)
[t, y, ~, ~, x] = rk_bungee_integral(T, n, g, C, K, L);
```

5.5 Automated camera system

Describe the question, and then answer it. In this case, you will fit an interpolating polynomial through the four points in your solution y that lie either side of the camera location. Then use that polynomial to solve for when the jumper passes the camera.

5.6 Water touch option

Describe the question, and then answer it. In this case, you will re-solve the equations with different parameters for L and k. Experiment to find which values work best for the water touch option, but include only the best combination that you found in the submitted code.

6 Conclusion

We are able to analyse different views of the bungee jump in order to meet the requirements of the bungee jump company with the Classical Fourth Runge-Kutta method which has been used to model the bungee jump. What the bungee company suggest is answered in order. The answers to question 1 and 2 use numerical solutions. Also, numerical differentiation and integration are used to solve the question 3 and 4.

The numerical solution and analysis for questions1, question2, question3, and question4 are well presented in this document. However, one of our team members (Saint) does not participate in this project, therefore, the numerical solution and analysis for question 5 and 6 are not presented at all. Due to the fact that the answers are based on the numerical model, further investigation and more accurate solution, such as analytical solution and real field experiment on the Story Bridge, are highly recommended if the bungee jump company are still interested in this project.

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