Final report of internship

JINQING XU

Variable Definition Table

|  |  |
| --- | --- |
| Variables | Definition |
|  | The normal vector of the tablet plane. |
| trial | Starting after clicking start button and ending when final lift up after a successful selection. |
| attempt | Starting after touch down and ending when lift up no matter selecting the target successfully or not. |
| entryFreq | The frequency of entry. |
| entry | The start point of the movement is outside the target and the end point of the movement is inside the target. |
| task axis | The line passing through the start button and the target. |
| task plane | The plane vertical to the tablet and intersect with tablet by the task axis. |
|  |  |

The Communication of leap motion and android

* **Challenge**

There are still no SDK for the connection of leap motion and android. So the two devices collect data separately. However, we need to find the relationship between 2D data and 3D data.

* **Method**

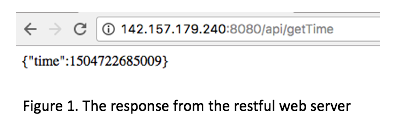
Since the android and leap motion programs run simultaneously, we can use the timestamp to locate the start and end of a trial in the leap motion data.

* **Difficulties**

We use the timestamp on the laptop to represent the time of a frame from leap motion data. And we use the system time of android to represent start-time and final-lift-up-time of a trial from android data. But the time of laptop and android cannot always be simultaneously. Even if I do adjustment, the difference of timestamp will be greater as time goes on due to the difference of clock frequency in different devices. We found that the clock frequency in tablet is somehow slower than that in laptop.

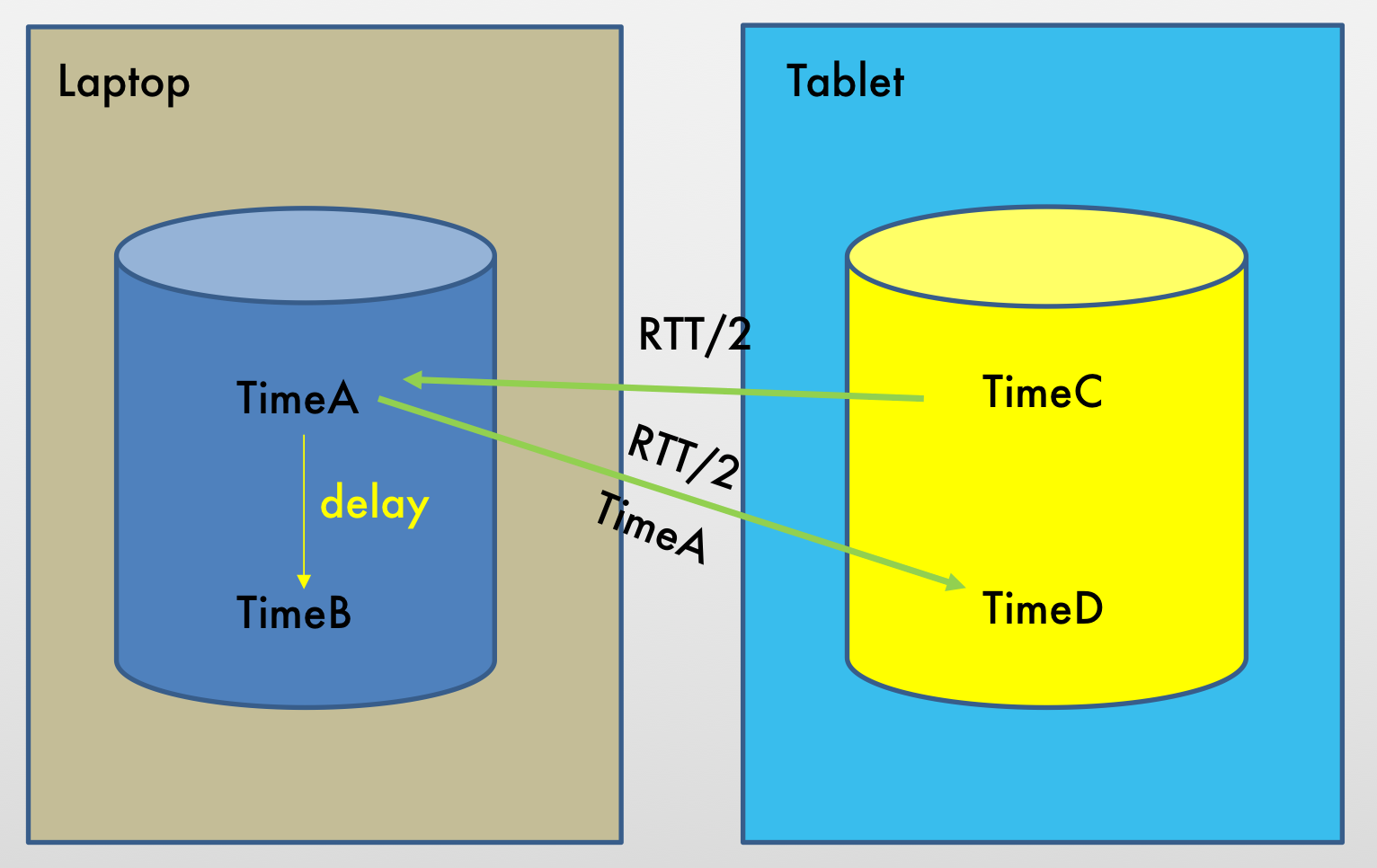
* **Solution**

The solution is to use the internet to find the difference of timestamp dynamically. Firstly, I started a restful web server on the laptop. Whenever a GET request is received, it will respond with the current timestamp of the laptop as shown in Figure 1.



Secondly, at the initial stage of android program, it sends GET request to the web server to get the current timestamp of laptop. By comparing the timestamp from android system to that from laptop, we can find the timestamp difference of android relative to laptop. After that, each time we record timestamp in android system, we add that difference.

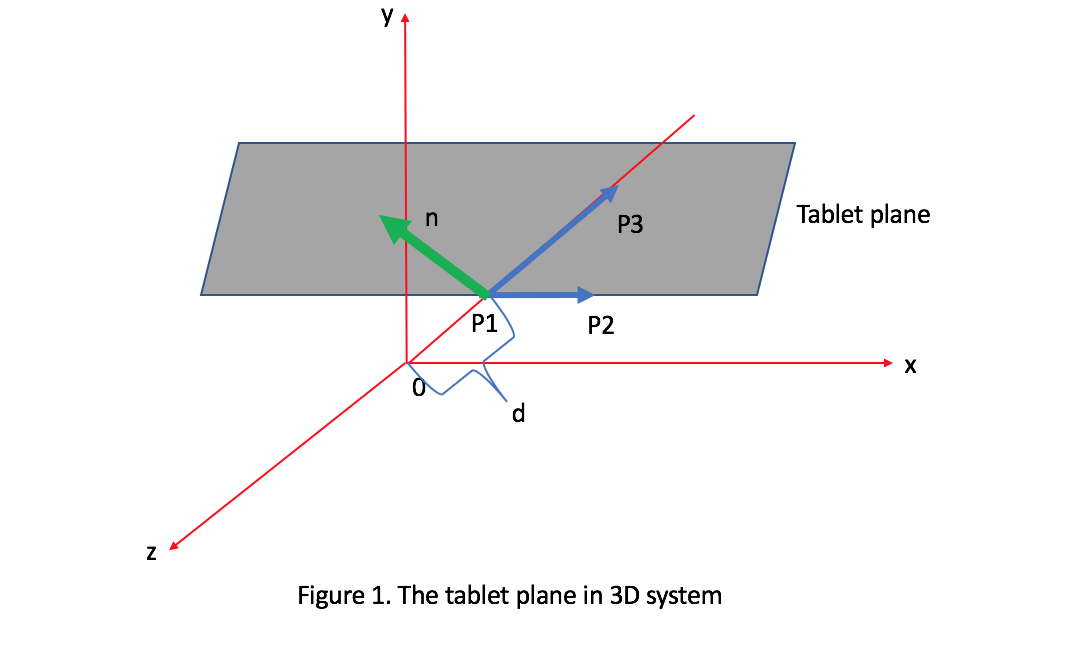
There is a tricky problem. After we send a request, there will be much network delay before we receive the response. To ensure the accuracy of timestamp from laptop, we need to take that delay into consideration. Before we send the request, we use beginClock to record the start time. After we receive response from the server, endClock is used to represent the end time. So Round-Trip Time is endClock minus beginClock. Since we get the system time of android after being responded, the delay should be half of RTT. Then the real timestamp from laptop should add up the delay on the base of the response value. Finally, we get the difference of timestamps from two devices.



Measurements

**Measures from Mackenzie:**

* **Variables that need to be defined in advance**
* **The normal vector of the tablet plane.**



1. suppose , and are three points on the tablet.

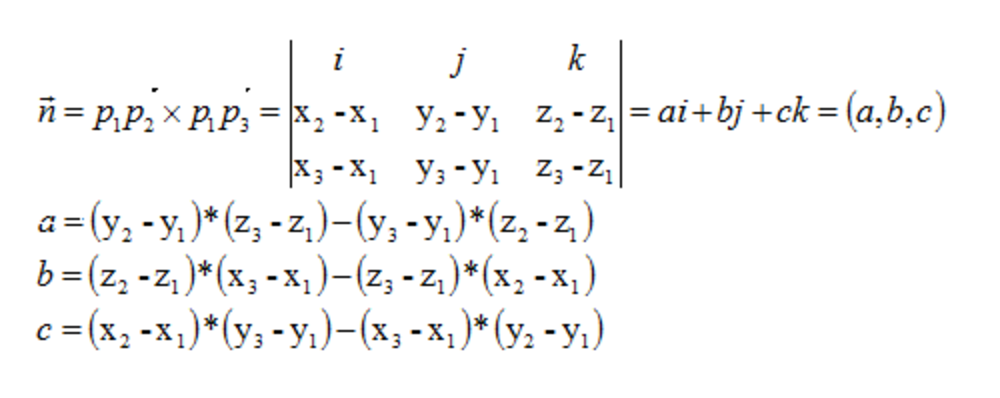
Let = (, , ) = ( , , ) = ( , , )

Then

Vector = (- , -, -)

vector = (-, -, - )

Let be the normal vector of tablet.



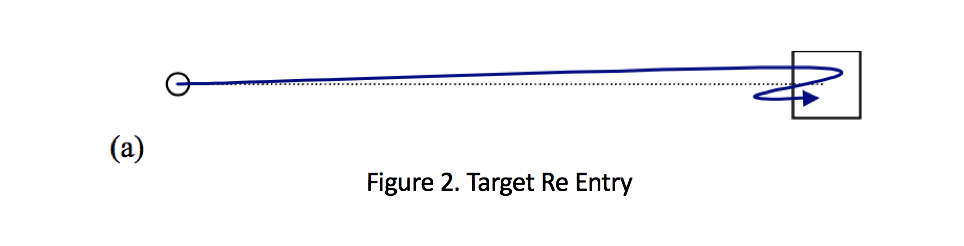
1. Let the distance between O and P1 be d

Then = ( 0,0,-d ) = ( 1,0,-d ) = ( 0,1,-d-1 )

1. Finally, we got the normal Vector of tablet = (0,1,1)

* **Target Re-entry (See codes in Appendix A)**
* **Definition**

TRE means first enter the target, then left, and re-enter again. TRE is detected when the finger moves on the tablet. An entry behavior means the start point of the movement is outside the target and the end point of the movement is inside the target. Let **entryFreq** be the frequency of entry. We accumulate **entryFreq** and each time when it is above zero, we minus its value by 1 to get the re-entry frequency since re-entry means entry again.



* **Measures**

1. **TRE**

The average re-entry frequency per attempt.

1. **First TRE**

The re-entry frequency of the first attempt.

* **Movement Direction Change (See code in Appendix B)**
* **Definition**

The direction change during a movement. There are changes in X, Y and Z direction.

The leap motion measures X, Y and Z value of the fingertip. When the current x is smaller than the previous one, the direction is **Left.** When the current y is smaller than the previous one, the direction is **Down.** When the current z is smaller than the previous one, the direction is **Backward**.

We record the previous direction and each time the current direction does not equal to the previous direction, a Movement Direction Change happens. Replace the previous direction with the current direction at the end of each loop.

* **Task Plane Crossing (See code in Appendix C)**
* **Definition**

The number of times that the paths of the finger cross the task plane.

If the finger is initially above the task plane and then below the plane, a Task Plane Crossing happens. We accumulate the frequency of Task Plane Crossing in a trial.

* **How to judge a point is above or below the plane.**

Firstly, we need to calculate the function for the task plane. To get the normal vector of the plane , we need to find two vectors vertical to it.

Since the normal vector for tablet plane is vertical to the normal vector of the task plane,

We got \* = 0 (1)

Since the direction vector of the task axis is vertical to the normal vector of the task plane,

We got \* = 0 (2)

Then we can get the normal vector (, , )

Let the 3D position of the start point be S(,,)

The function of the task plane is

\*(x-) + \*(y-)+\*(z-) = 0 (3)

To judge whether a point P ( , , ) is above or below the plane, we put its value into the function (3)

D=\*(-) + \*(-) + cn\*(-) = 0 (4)

If D > 0, P is above the task plane

If D==0, P is on the task plane

If D < 0, P is below the task plane

* **Movement Offset (See code in Appendix D)**
* **Definition**

Movement Offset means the mean deviation of finger from the task plane. The deviation is measured by the distance from the finger tip to the task plane. When the finger is above the task plane, the deviation is negative. And when the finger is below the task plane, the deviation is positive.

MO =

* **Calculate the distance between a point P and a plane.**

Let the line passing through P be l. Let the intersection point of l and plane be C. The distance between P and the plane equals to that between P (, , ) and C (.

1. **get the function of l.**

We have already calculated the normal vector (, , ) of the task plane when we calculate task axis crossing. It is also the direction vector of l.

The function of l:

=k (5)

1. **get the intersection point C.**

From (5), we can use k to represent x, y, z

x=\*k+ (6)

y=\*k+ (7)

z=\*k+ (8)

Put x, y, z into the function of task plane (3)

We get

K= (9)

Then put (9) into (6),(7),(8)

We can get C (.

1. **calculate the distance between P and C.**

D=

* **Movement Error (See code in Appendix E)**
* **Definition**

Movement Error means the mean deviation of finger from the task plane. The difference to Movement Offset is that the deviation is measured by the **absolute** distance from the finger tip to the task plane.

ME =

* **Movement Variability (See code in Appendix F)**
* **Definition**

Movement Variability means the standard deviation in the distances from the mean distance. Distance, as mentioned in Movement Error and Movement Offset, is the distance between sample finger tip and the task plane.

MV=

(sample standard deviation should divide by n-1)

**Measurements from Hwang**

Hwang thinks that a trial is consisted of several submovements. So all her measurements is based on this concept.

* **Submovement (See code in Appendix G)**
* **definition**

1. **The start of submovement**

When up to 100ms of frames which speeds are above zero occurs.

We need to accumulate 100ms continuous frames which speeds are above zero. When a frame’s speed is zero, we need to abandon the previous accumulated time duration and start from the next frame.

1. **The end of submovement**

There are three situations:

1. The speed returns to zero
2. The acceleration speed change from negative to positive while the speed is less than 75% of the peak speed.

Firstly, judge whether the previous acceleration speed and

the current one is positive or negative.

Then, if the previous acceleration speed is negative and the

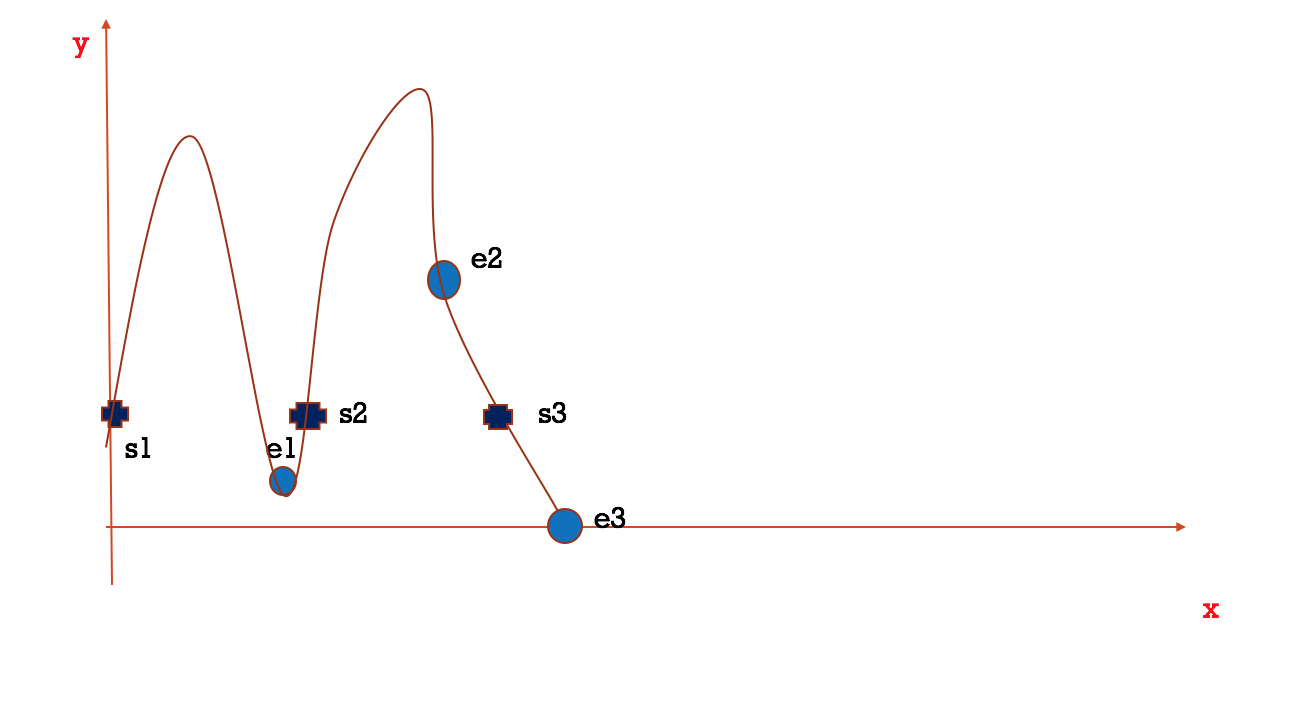
current one is positive, judge whether the current speed is

smaller the 75% of the peak speed in the

1. Brake occurs.

A relative maximum negative accelerate speed which is big enough to be considered as brake.

A relative maximum negative accelerate speed means larger than the previous negative ones and also larger than the next negative accelerate speed. ( A local maximum)



a sample submovement

s1 represents start one, e1 represents end one (the accelerate speed change from negative to positive and speed is less than 75% of the peak speed)

s2 represents start two, e2 means end two (sudden brake occurs)

s3 represents start three, e3 means end three.

* **Measurements**

The number of submovements.

* **Pause (See code in Appendix H)**
* **Definition**

The speed is almost zero.

* **Measurements**
* **The pause frequency**

How many times does pause happens.

* **The mean pause duration**

How long does the pause last.

* **The distribution of pause**

Measured by the distance from target.

* **Verification Time (See code in Appendix I)**
* **Definition**

The time from the end of the last submovement to the end of the trial.

After we have split the trial into submovements, we get a list for submovements. Then we use the final lift up timestamp to minus the timestamp of the last submovement.

* **Function**

Verification time reflects the uncertainty or hesitation before the participant finally touch down.

* **Number of submovements in total (See code in Appendix J)**
* **Definition**

The total number of submovements in one trial.

After we get the submovement list, we count the length of the list.

* **Distribution of the peek speed (See code in Appendix K)**
* **Definition**

The maximum speed among submovements in one trial.

When we go through the frame index to find the start and end of submovements, we use a temporary variable to record the maximum speed during a submovement. Then we keep update the peek speed in one trial with the largest peek speed in submovements.

**Original Measurements From Our Work**

* **Decision Making (See code in appendix L)**
* **Definition**

Decision Making means when the finger is very close to the tablet and also close to the target.

* Close to the tablet.

Calculate the distance between the finger point and the tablet touchscreen. The math principle is already given in [the definition of movement offset](#MovementOffset).

The distance should be less than 15mm.

* Close to the target.

Let the line passing through the finger point and vertical to the tablet be l.

Let the intersection point of l and the tablet touchscreen be C ().

The calculation of the 3d coordinates for C is already mentioned in [the definition of movement offset](#MovementOffset).

C is on the tablet, and we calculate its distance from the center of the target.

The distance should be less than (1+0.25) \* R, R means the radius of the target.

=

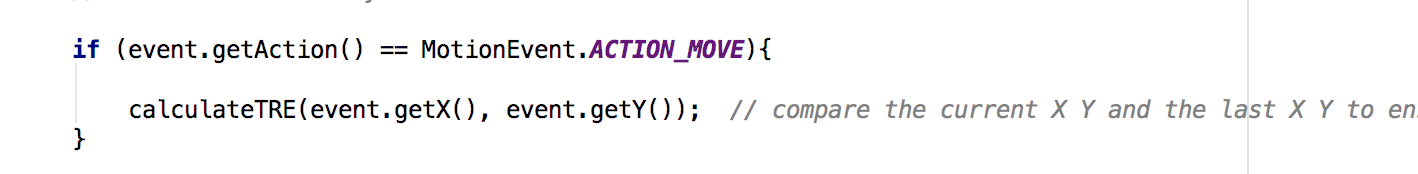
< (1+0.25) \* R

* **Function**

Though verification time can reflect the hesitation and uncertainty of target selection, it only takes the last submovement into consideration. However, that uncertainty can happen multiple times, the participant might keep his finger near the target then slip away and after that hesitate again. So we need a new measurement to better reflect the uncertainty.

Appendix A

CalculateTRE function is in the android code and it’s called when a move event is detected.

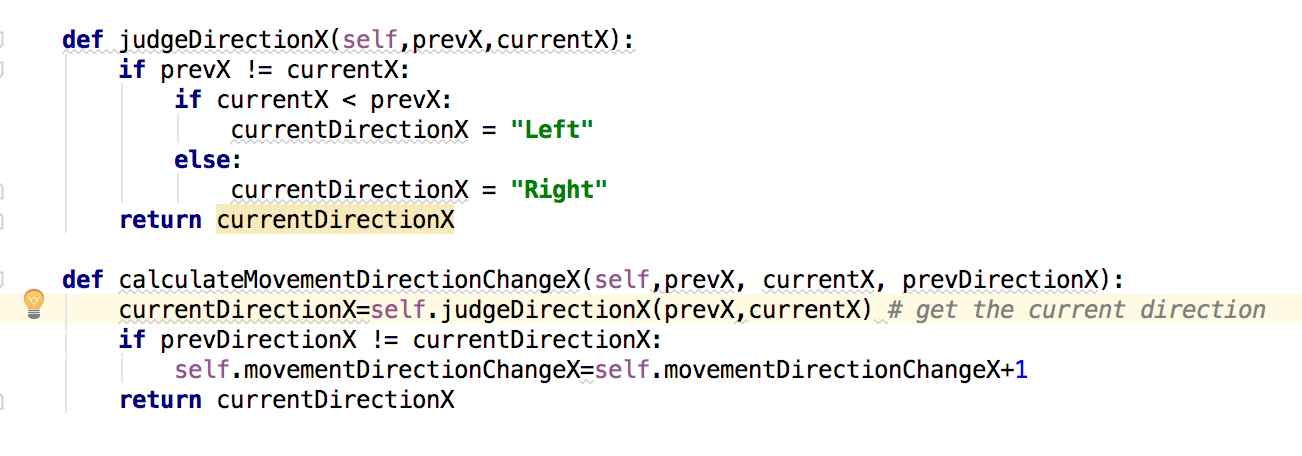
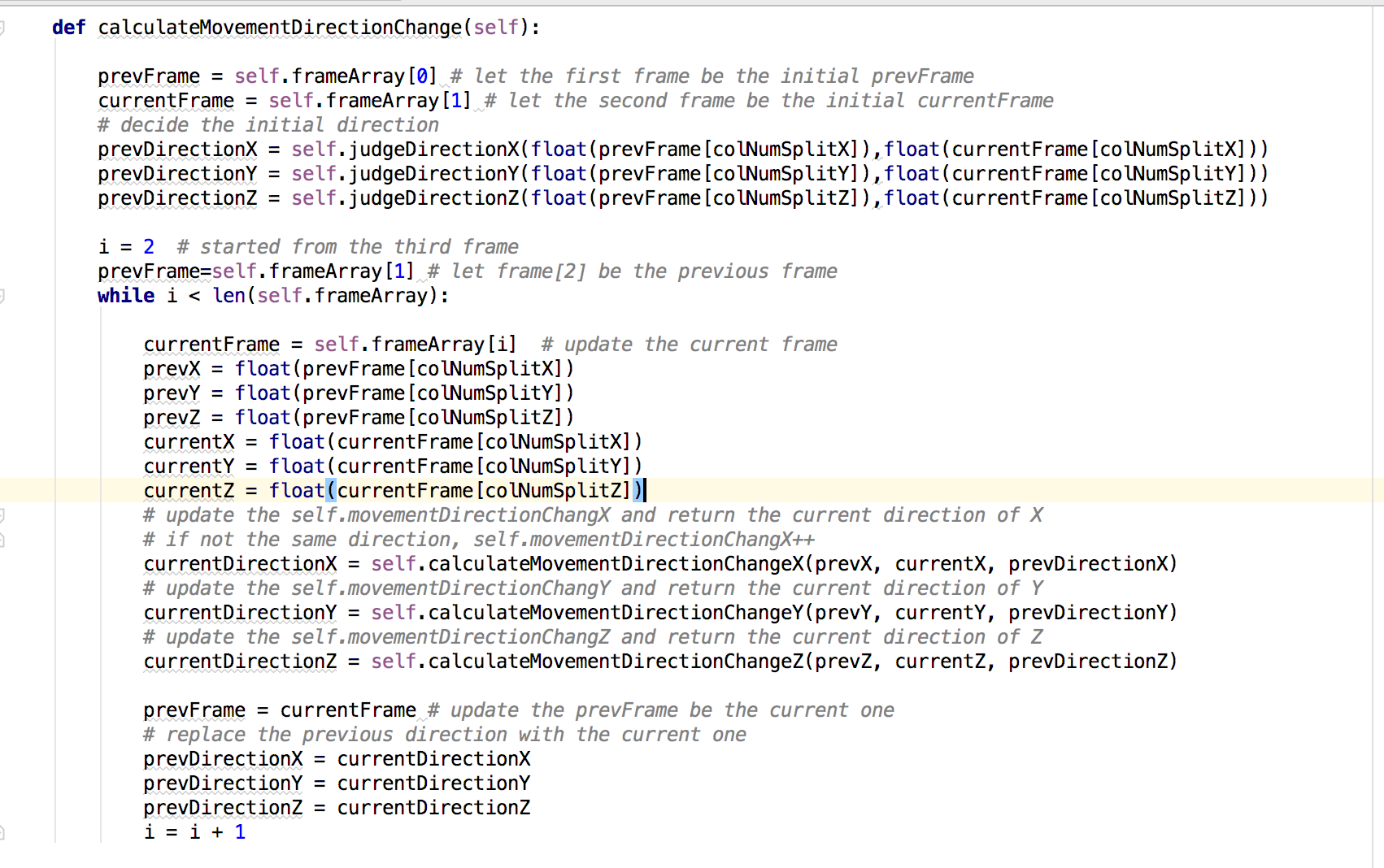




Appendix B

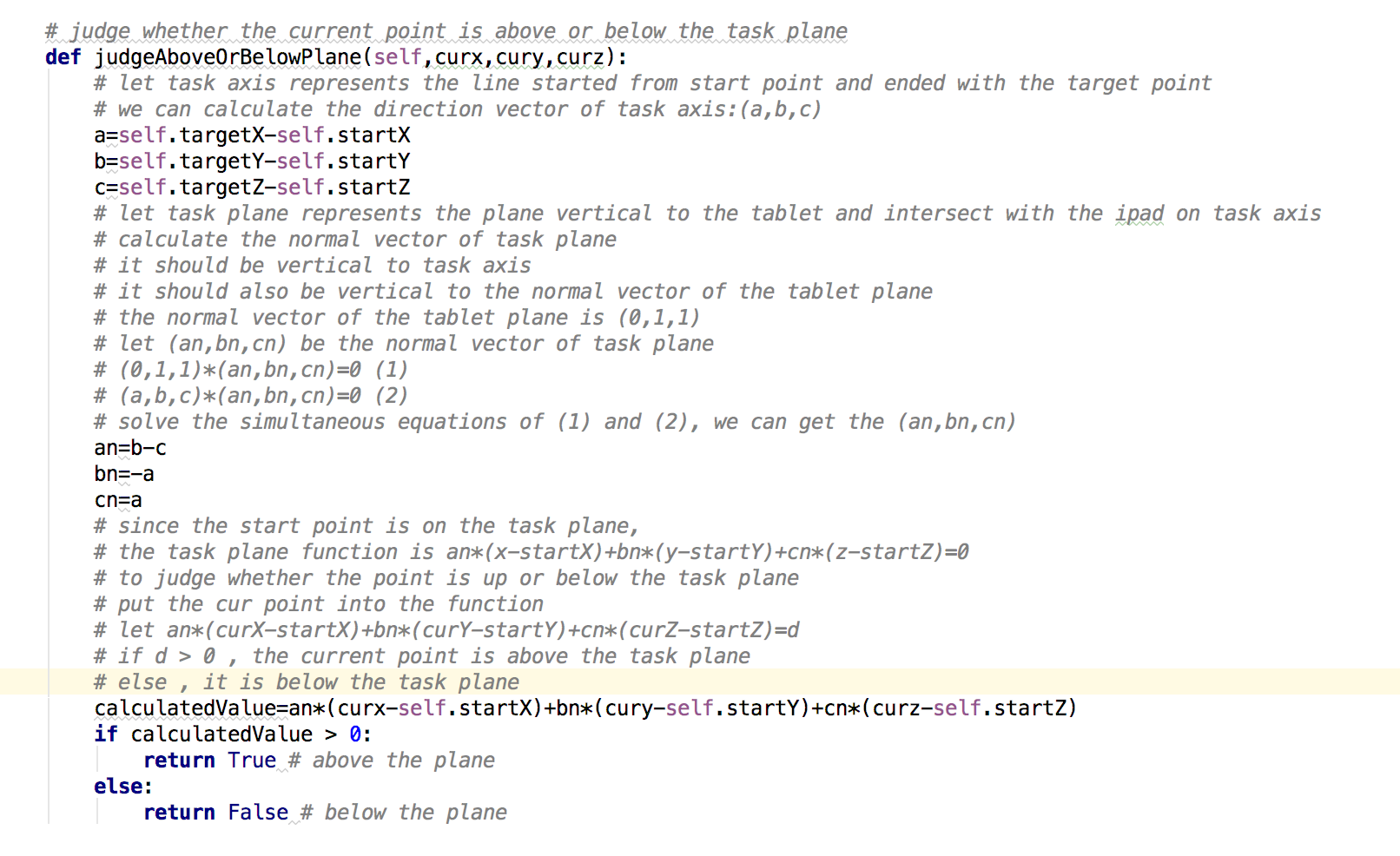
Firstly, using the first and second frame to judge the initial direction.

Then let second frame as the initial prevFrame, the loop begin with the third frame.

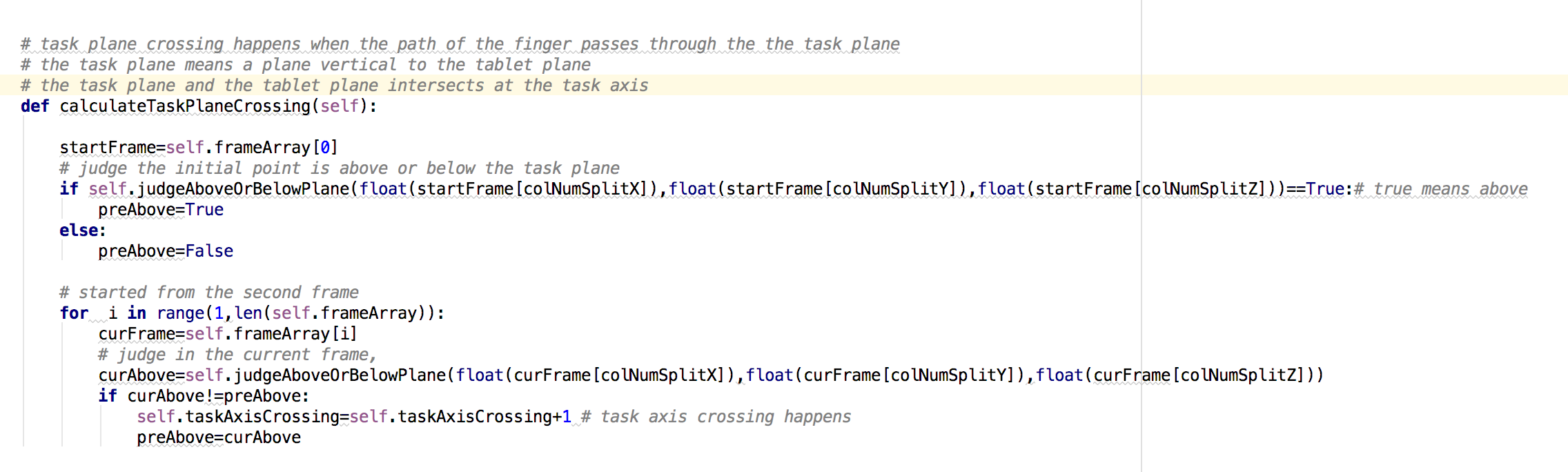


Appendix C

* Judge whether a point is above or below the plane

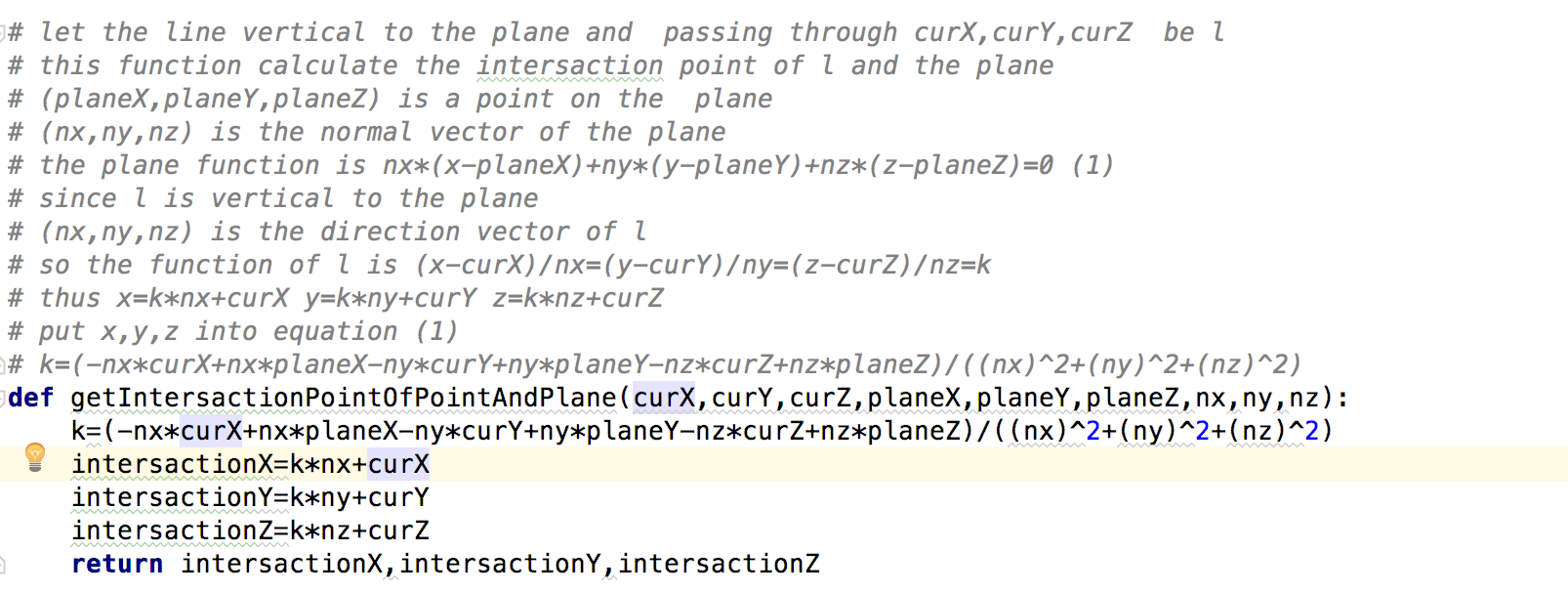


* Calculate Task Plane Crossing

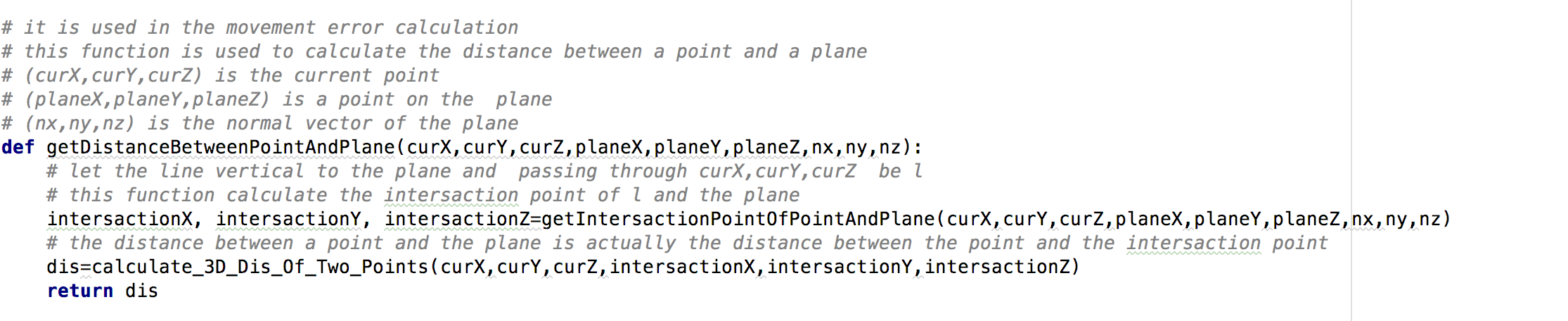


Appendix D

* get the intersection point of a line passing fingertip point and the tablet touchscreen.



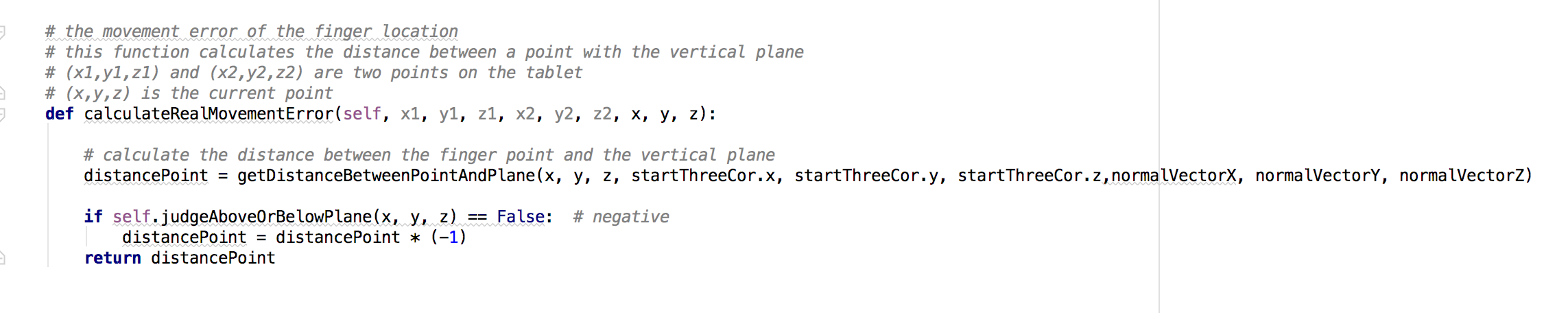
* get the distance between a point and a plane



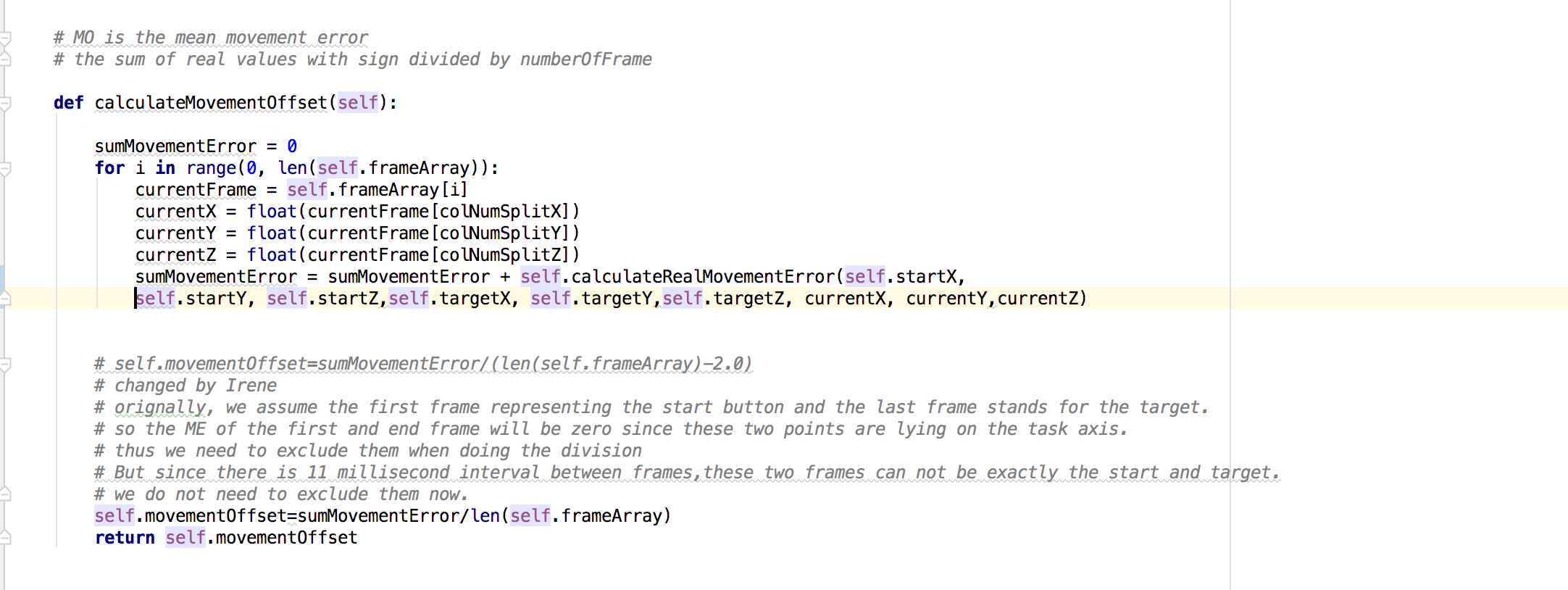
* get the real distance (positive/negative) between the fingertip position and the task plane

Firstly, we calculate the distance between the fingertip position and the intersection point.

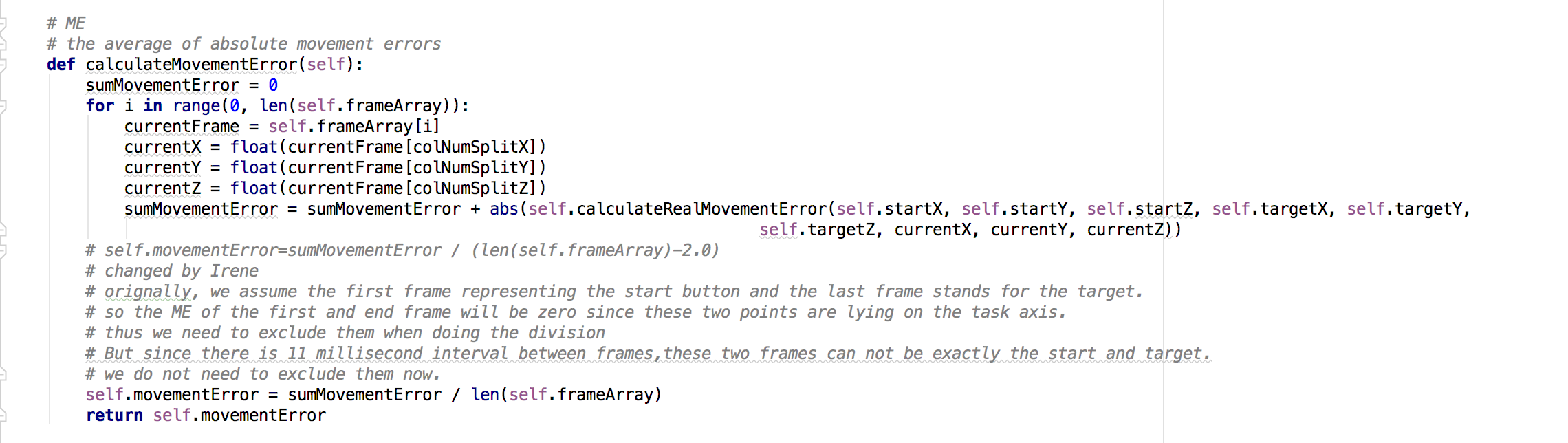
Then, we need to judge whether it’s above the task plane or beneath it in order to decide whether it’s positive or negative.



* get offset ( the average of mean distance)



Appendix E

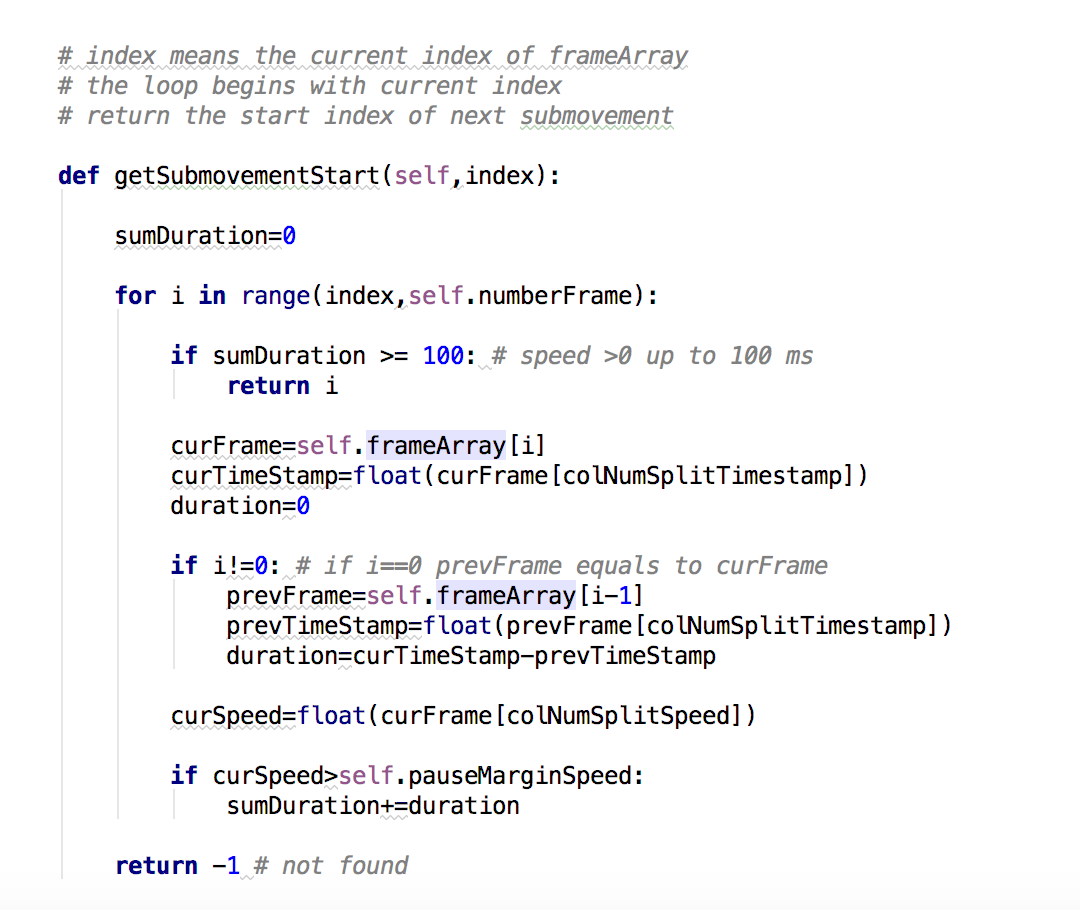


Appendix F

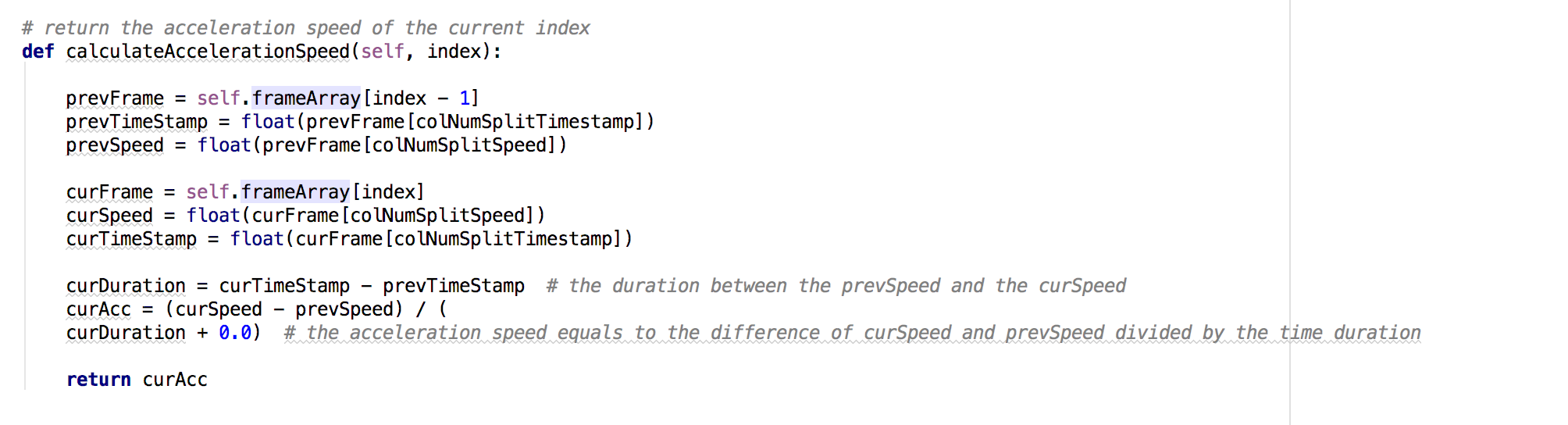


Appendix G

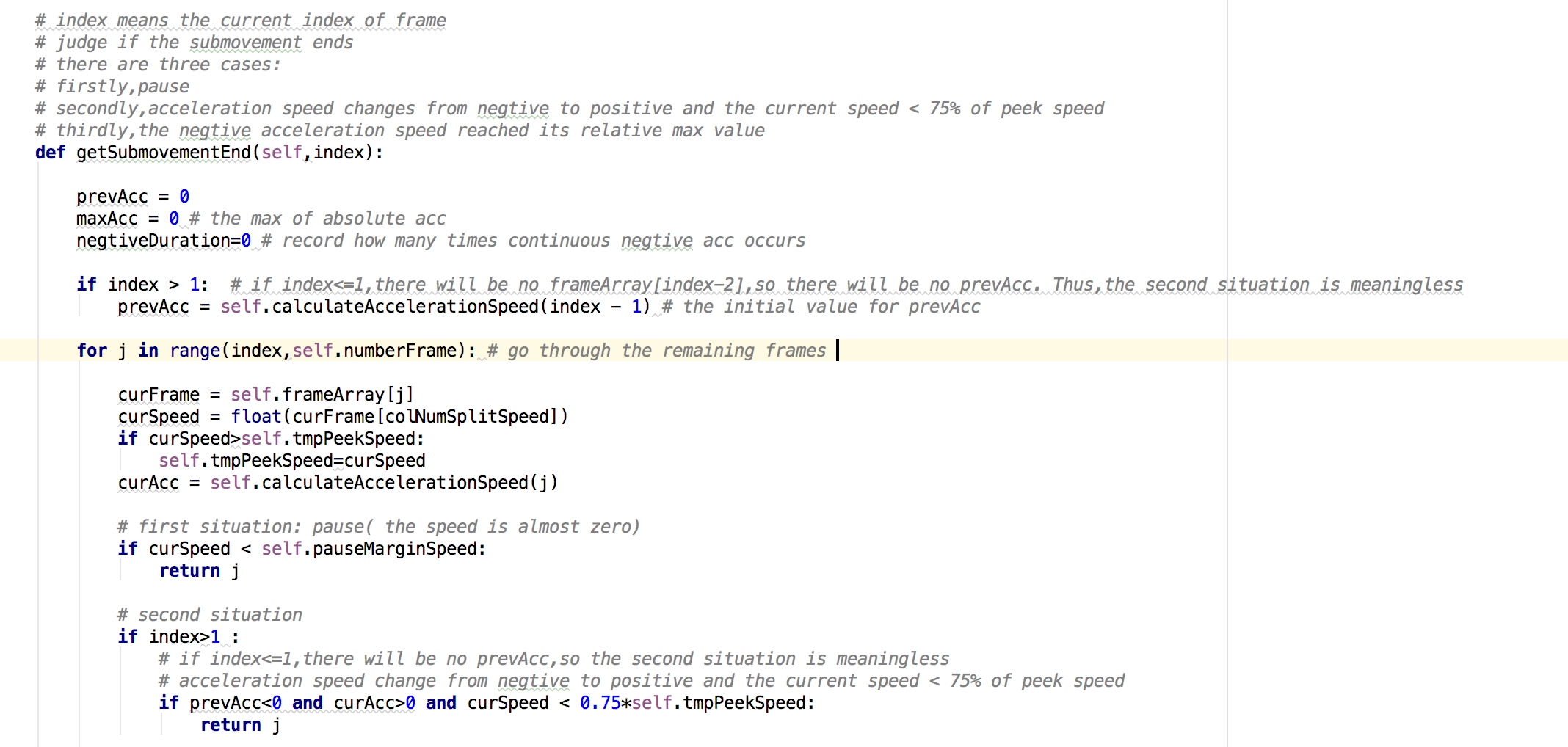
* **The start of submovements**



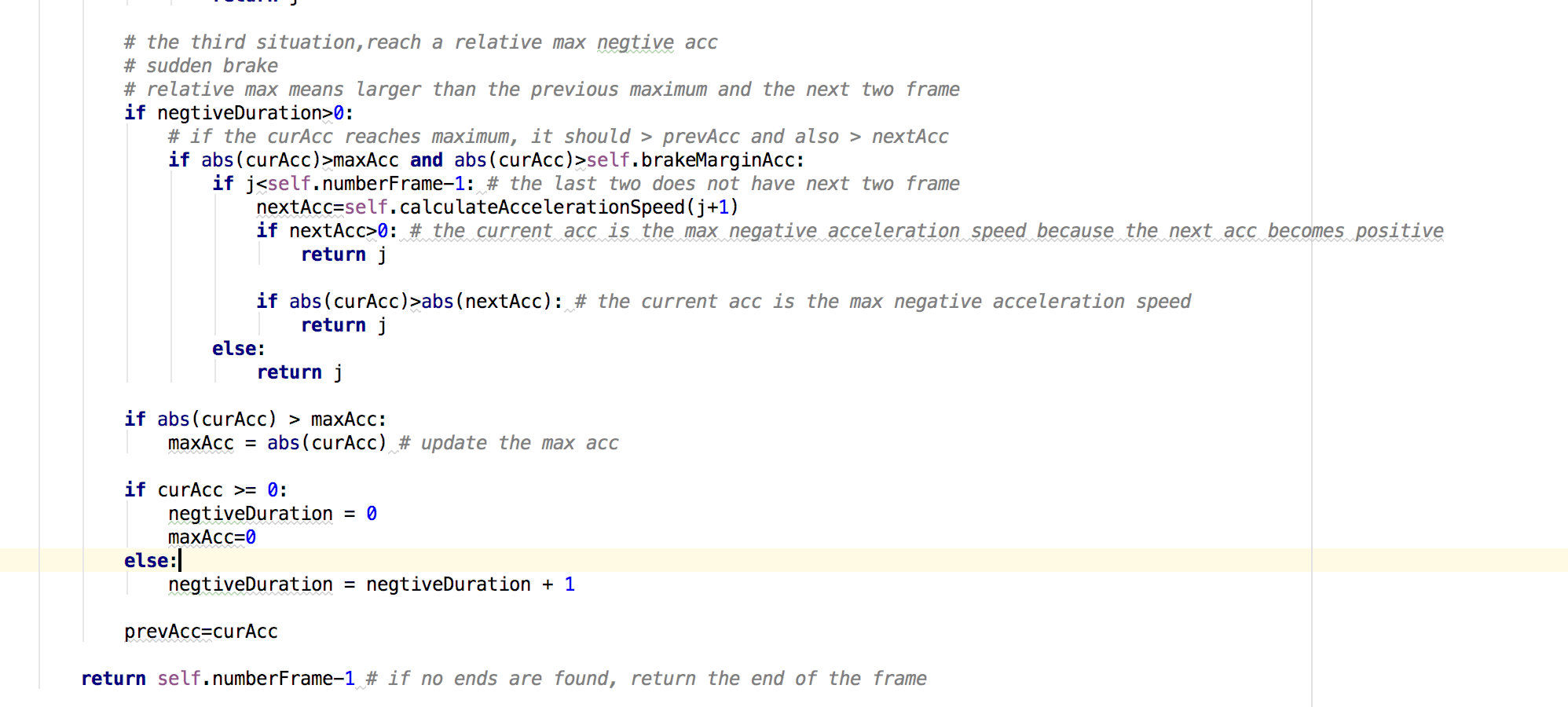
* The accelerate speed



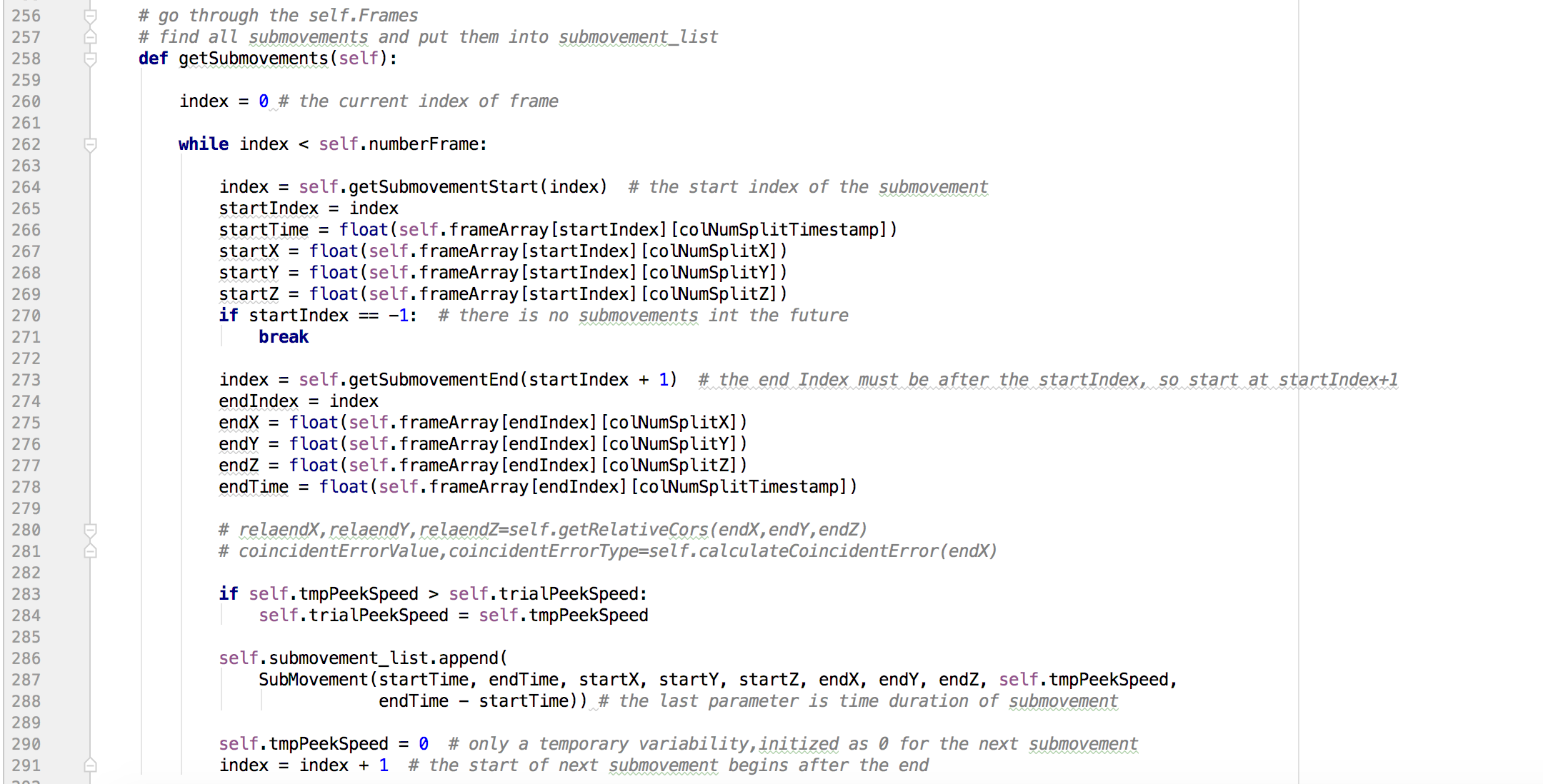
* **The end of submovements**
* The first and second situation



* The third situation

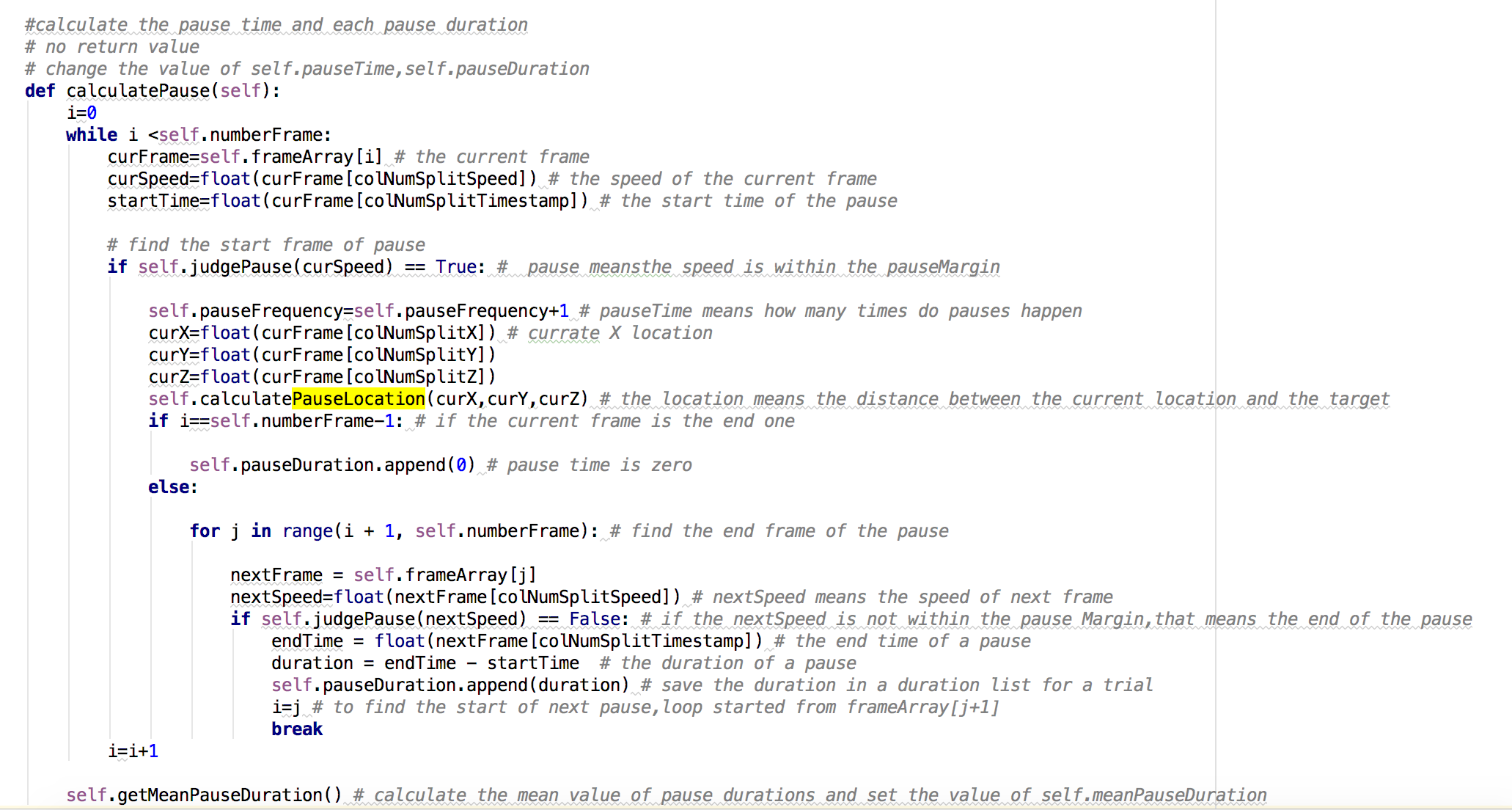


* Go through frames to find start and end of submovements. Then append all the submovements in a list.

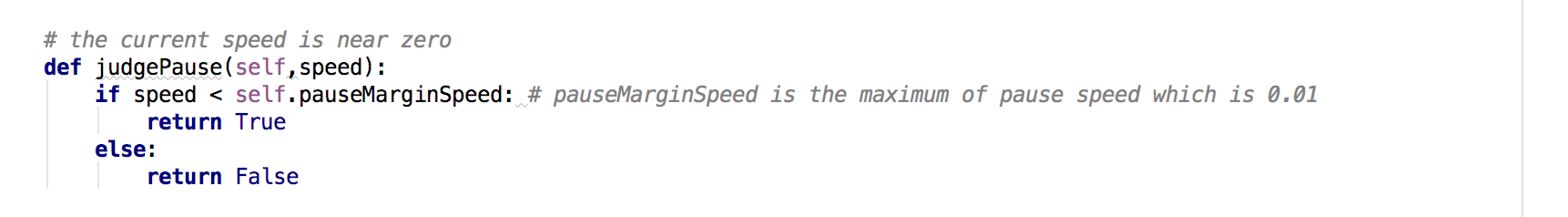


Appendix H

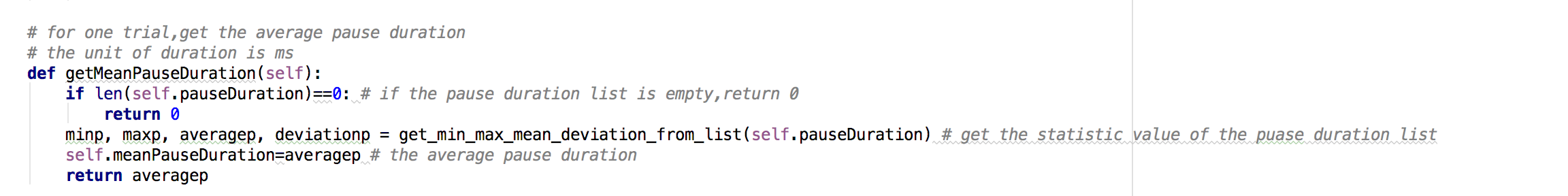
* Go through the frames to find the start and end of a pause. Then calculate the duration and update the pauseFrequency.



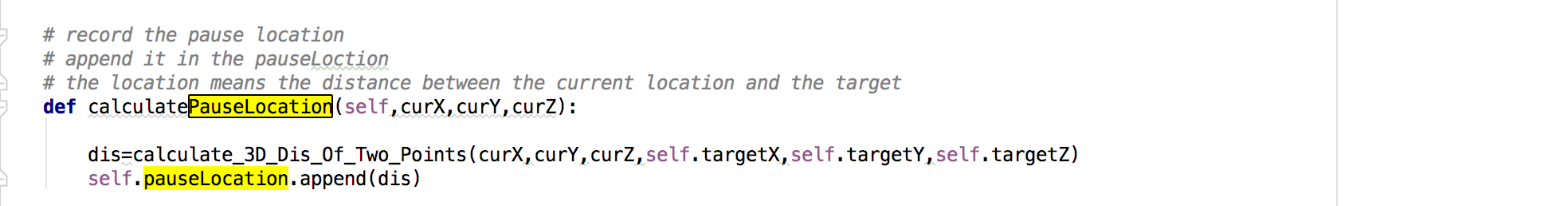
* Judge pause



* Get mean pause duration

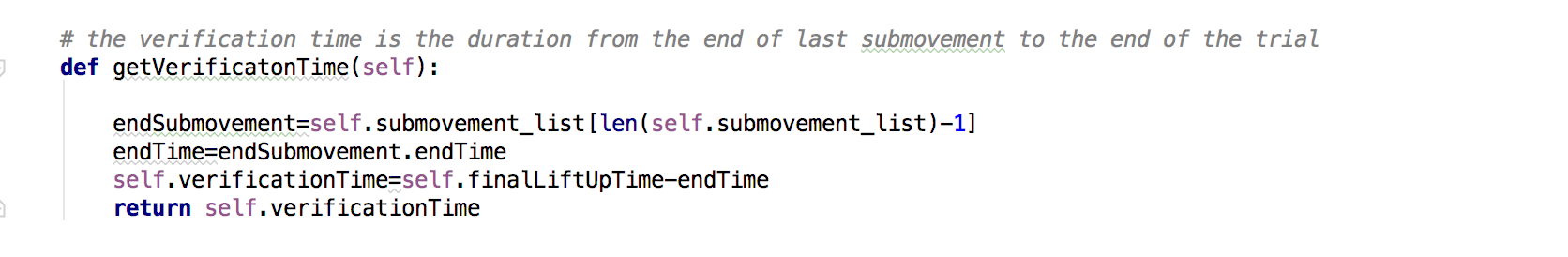


* Get pause distribution



Appendix I

* The calculation of verification time



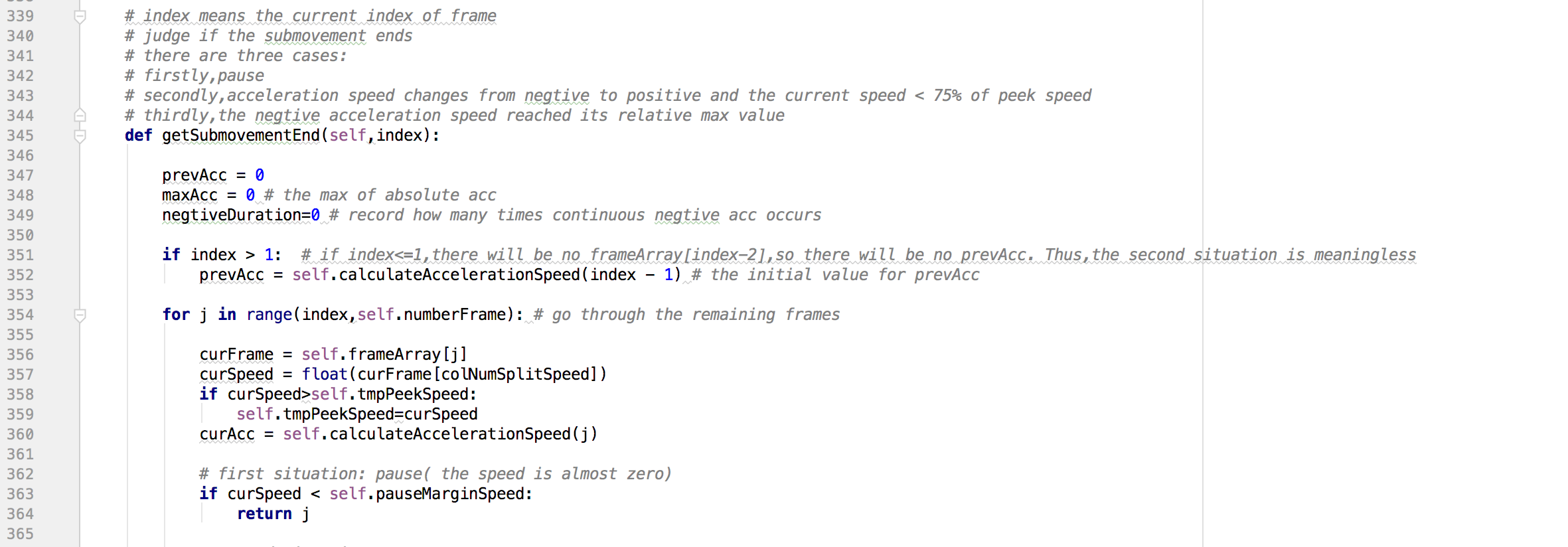
Appendix J

* The calculation of the total number of submovements

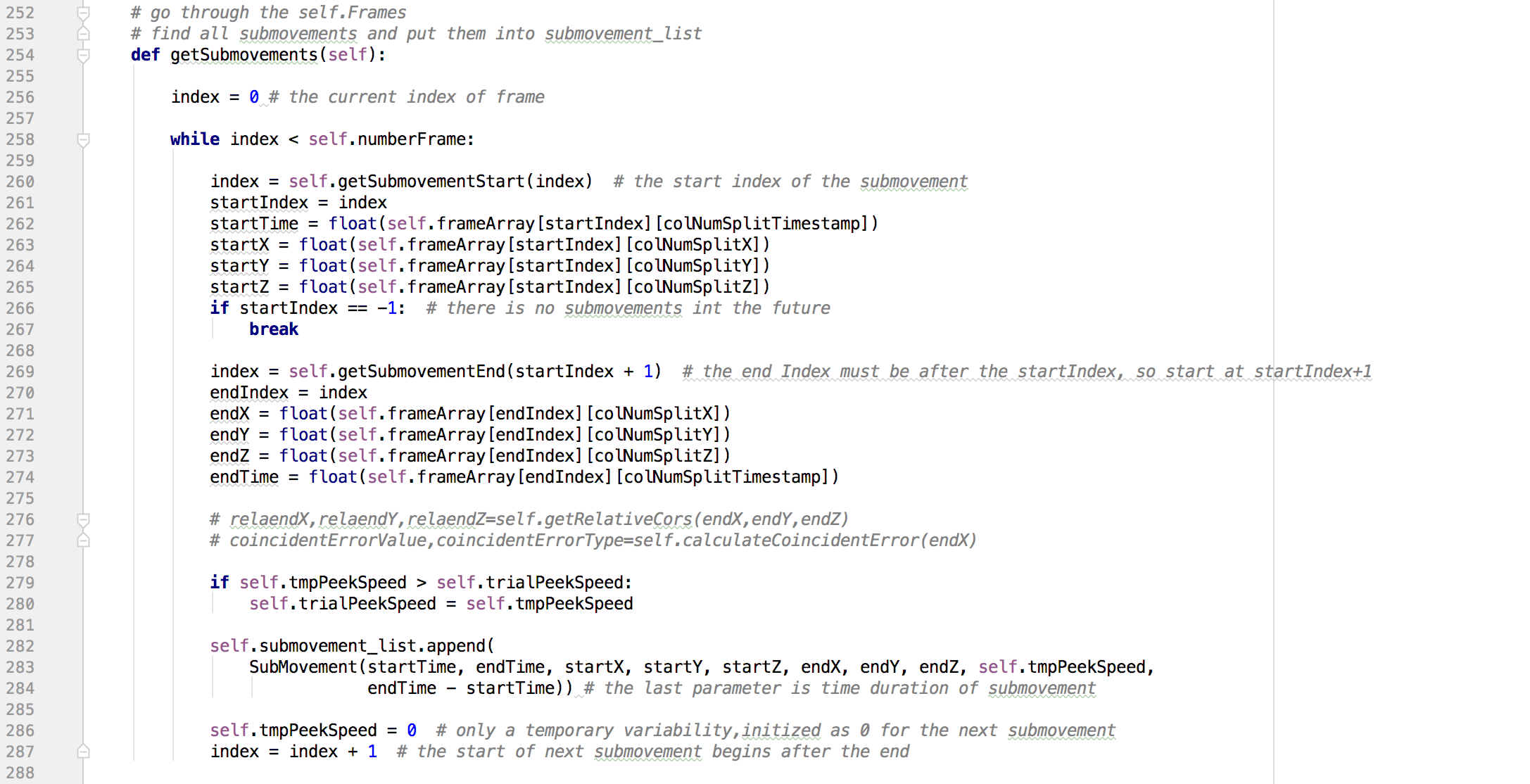


Appendix K

* Get the max speed in each submovement (line 358-line 359)



* Get the peak speed in one trial (line 279 to line 280)



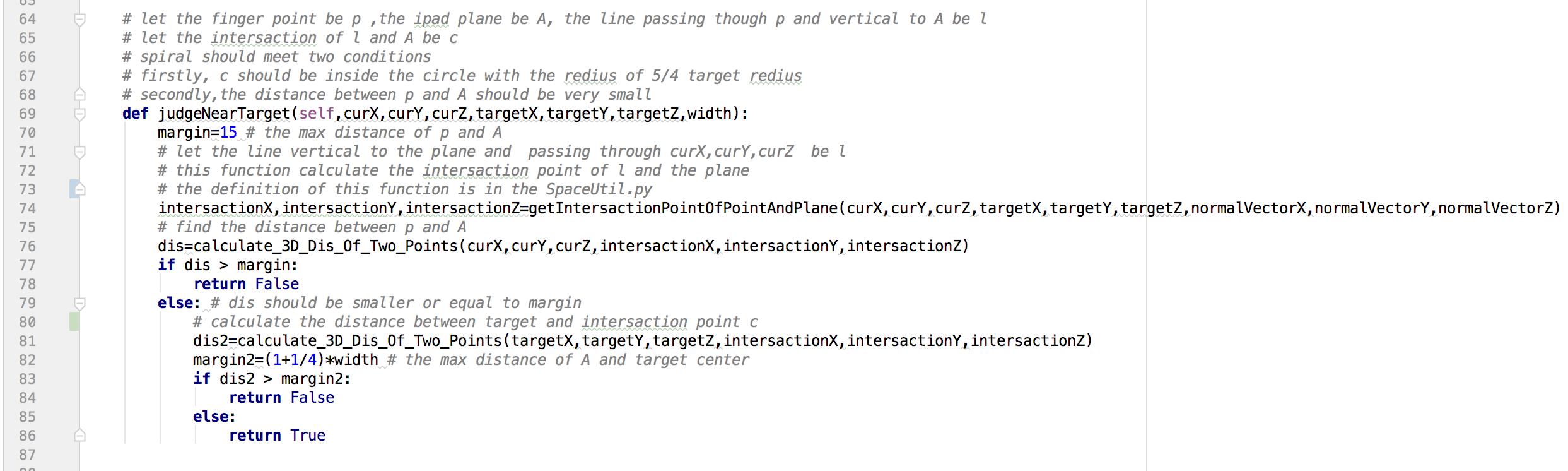
Appendix L

* **Judge whether the fingertip position is near the tablet and close to the target.**

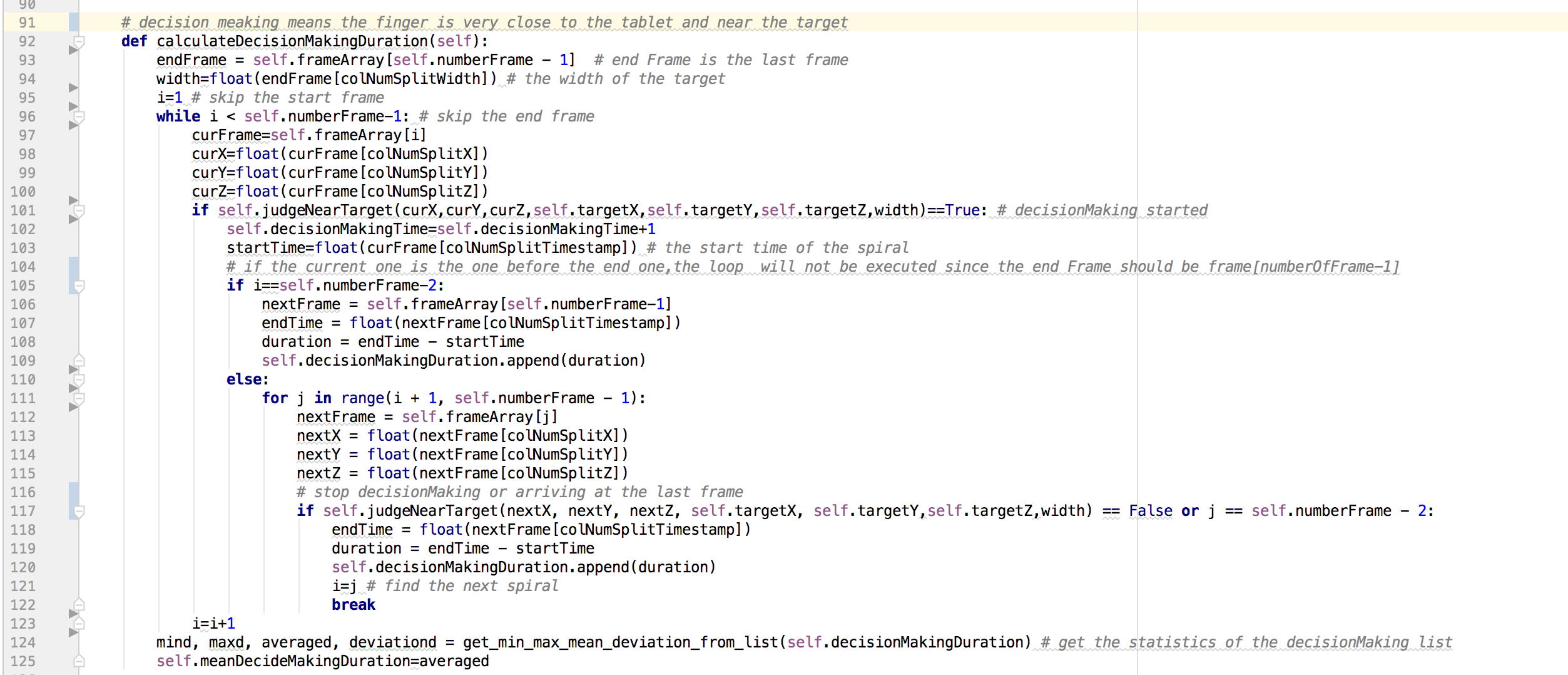
Firstly, calculate the intersection point. ([definition code](#intersection))

Secondly, calculate the distance from the fingertip position to the tablet. ([definition code](#disBetweenPointAndPlane))

Thirdly, calculate the distance from the intersection point to the target.



* **Calculate the decision making frequency and mean duration**

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