Computational Science and Engineering using Python
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Lecture - 06
Plotting in Python

Now, I need plotting. So, python; one beautiful thing is it can really plot complex functions and it is quick and also integrated with coding if programming. If a programming in c, plotting is way too difficult. There are some libraries, but nobody plots in c as far as I know. That is a old guys may, but nobody does plotting in c. Either use all these packages MATLAB, Mathematica or Python. So, I will show you how we can do things with plotting.

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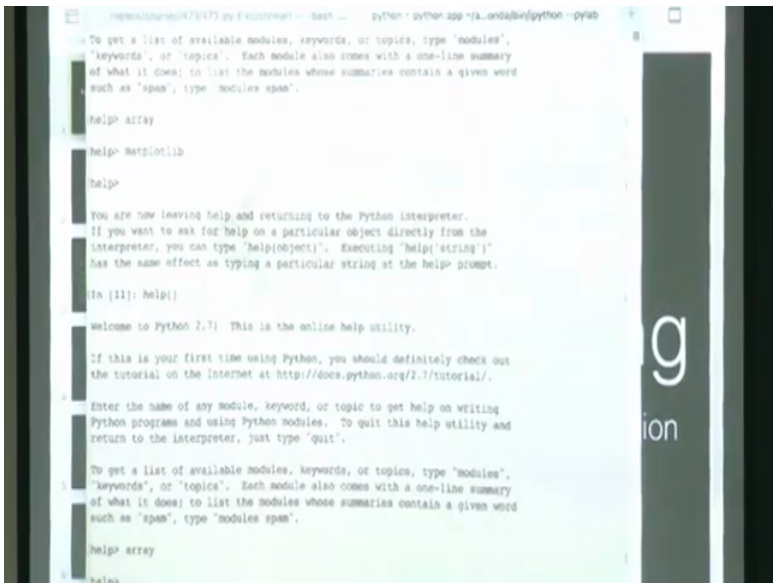

So, from the help by the way I just have to quit otherwise I will not get that interpreter in one out one. So, quit I got it here. So, I should make it. So, next 2 classes I will just do plotting.

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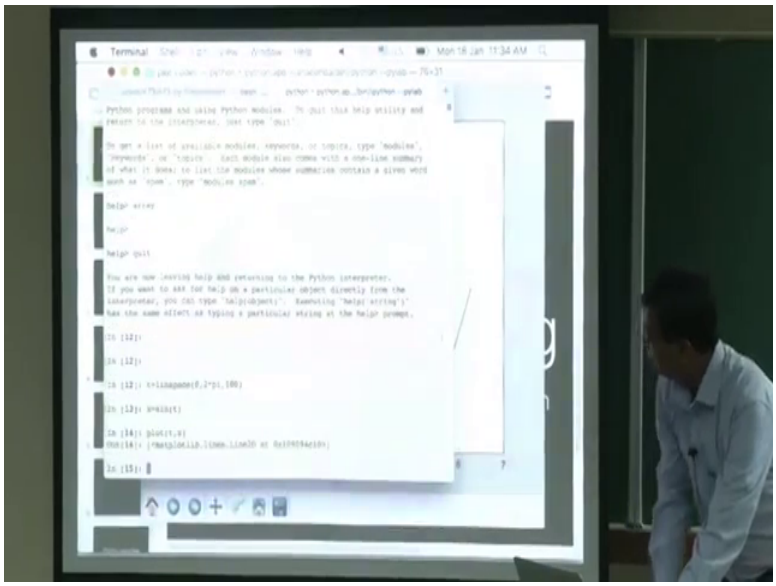

So I think one and half class I should finish.

So, this is part of pylab. So, you do not need to anything else that is python minus minus pylab and I want to plot. So, let us say plot x comma y, no. So, x is an array, y is array. So, it will plot 2 arrays; linear arrays. I am doing 2 d plot. So, let us say a plot for oscillator. So, oscillator; I will start from time t equal to 0. So, I should do linkspace; so time 0 to 2 pi. So, line phase is very useful function 0 2 star pi. So, please see this everybody can see this. So, line 2 pi and how many numbers how many numbers do I want; 100 is good enough. So do not put 2 many of them. So, 100 is good. This time; so T is time, I am looking for x. So, x is sin T frequency is omega is 1. So, x is sin T. Now I want to plot. So, is trivial plot T comma x. So, it has come in the background.

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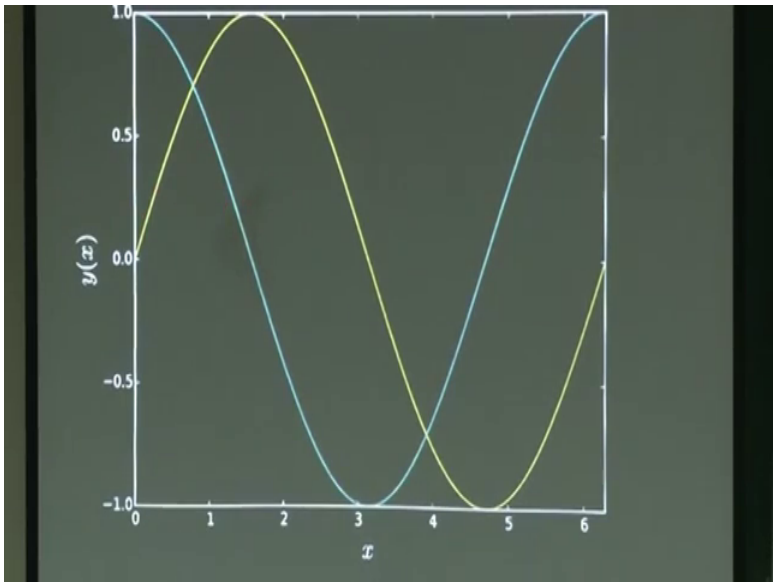

So, this is what has come. So, x is 0 to 6 point what is it 2 8. So, I do not like this area means they looks is if (Refer Time: 02:50) does not stop. So, we say well, I want to make the x axis 0 to pi only.

So, this is a function called x lim; x limit; it put it take in the side. So, you say x lim. So, pylab is very nice that I do not need to remember its part of matplotlib, this is all part of matplotlib; remember, this function I was telling you package matplotlib. So, I do not have to say matplotlib right now. Pylab has imported all of it and is making available. So, x limit will take an array. So, limit of x minimum to maximum. So, is an array; so have to put within the bracket; square bracket 0 to 2 pi. So, 0 to pi; I limit my x. So, now, if you see the plot, he did it, it corrected it; 0 to pi here.

I could also write this label in terms of pi into 2 pi. This equal x takes I will not do all of it live, this is like I also do not remember all the syntax, but I will give this packages; my functions and you can tinker with it and you can write it. I will not put label. So, I want put label here and label there. So, is very easy, so x label. So, we will label the x axis even though I call the x axis is t, x label is keyword for the x axis, even though it is t. So, do not say t label; t label it will not understand. It is x label and here also t within quotes.

So, if I just say t let us say just put t, it will work and I will put t below. So, t has been cut but we can also; when I save it will come, but these t should be math t. So, it also takes latex syntax. So, latex if you remember math is seen dollars, no, latex is; you should be

knowing latex or if you do not know; you can learn slowly you put latex symbol in dollars; this for latex.

So, it is a string. Now it has t. So it has overwritten it. So, t is there, I put y label; quote dollar. So, you can see that x t in the right. So, you can easily do plotting we can save this plot; how do you save this plot or you can zoom inside the plot. So, you can zooming in; you can do by this. I can zoom in this part, but you want to go back. So, you put this form; I want to save it; just click here, I will tell you where to save it. So, I can save a figure one. So, this is saving as P and G. So, this is the format, I want PDF and I just save PDF. So, PDF is one; you can change the name of the file. So, all of it; you can save; it is saved in wherever you want you can save it, I will not save it here. Now want another figure. So, that let us say energies x square, so to get another figure as a figure like this. So, it has created figure 2. So, figure 1 is there behind. So, figure one is definitely there. So, you create another figure. So, windows you should be see figure as figure is somewhere behind.

So, I want to plot x square. So, I say plot e comma x square is x; x is an array, right, x square we will work, but I want with the some other color. So, could say red dot. So, these will be dash dash wait; what is this red? It does not require in the string, it is string. So, is red with the dash dash.

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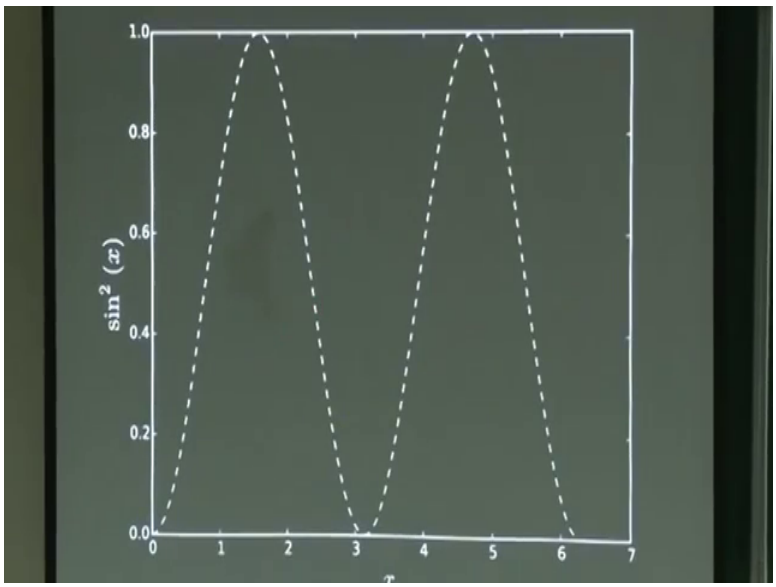

So, all that you can find is help you want change. So, is dash dot. So, you can do lot of stuff very simply. So, in your course, you can in quantum mechanism, something in simply plot you no need to believe the book you can just see whether it is correct or not some books plots a wrong I can tell you that you can see yourself. So, that is how we do it, but let us do slightly systematically, I want to make this figure more nicely, I want the size of the figure. So, if I make it too bigger figure then even a shrinket; the font becomes small.

So, I just run some of this stuff for 2 d plot as well not everything you need to do it, but I think is good idea at that; you learn some of this how do tinker with the size. So, in your report; you write for project you should be giving a good figure or for your other work.

So, I will just go through the code which I have written. In fact, this is by Abhishek; some of it was done by the PhD student. So, this pylab; I just showed you.

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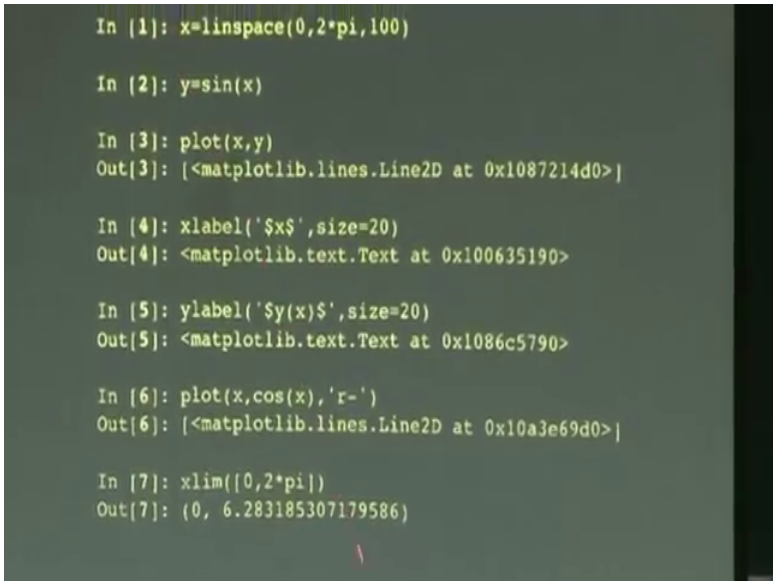

So, this is what I just did that I change the size of this label by saying size is 20. So, this is called twenty points in each point is some inch 20 x; limit you can sent set the y limit you can do all that. So, this is the figure, but 2 of them you put combine many figures in 1 command or you can put 2 commands different colors. So, this is the figure I inverted my. So, the color coding is not exactly same as what; I put in the code because it is recording the white does not look good. So, this has been changed. So, color will not be

exactly same as what you. So, I will share the PDF file and the PDF file color will be will be exact like what comes from the code.

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So, let us look at some of the commands. So, you can make a file; you no need to say x label x limit y limit all that time. So, that file; again change only in some parts and you can plot beautiful plots.

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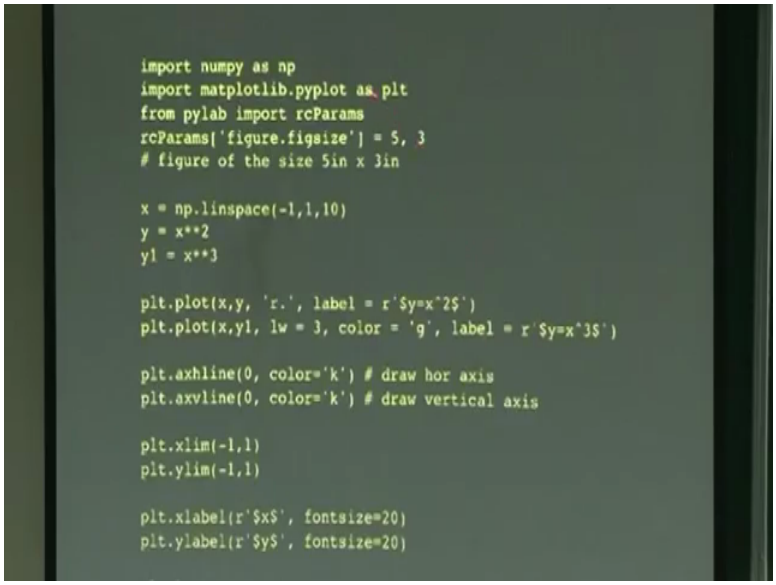

So, this one of the file for plotting 2 digits; so, you go from the top file will require the package without that; it will not plot file have an imported all of it, but the file does not

know what pylab has imported. So, I need to import this call mathplotlib and I import as PLT. Now this part is nice is part of pylab called RC parameter and this set the size. So, figure of size 5 inch by 3 inch**.** So, it is a nice 5 inch with 3 inch fits nicely in a page in a book page. So, I want to plot a x square and y squx cube; so linspace again minus 2 1 with 10 points. So, I plot x comma y with red dot.

So, this will be dot will be; I am not sure, this should be dot; I forget this will dot is probably dot label. So, I have putting the label of this plot. So, you will see label will come. So, this called legend. So, legend tells you which color is what. So, I will I will show you the figure. So, this will plot x comma y and it is y equal x square and next one is y equal to x cube is color green color will not come out right it is set I have inverted the color for video recording this for axis. So, this sets the axis; x axis and y axis horizontal axis and vertical axis h and v.

So, though horizontal axis and vertical axis I set the limit minus one to one and also the color of x label and y label I put this legend as some location 4 right corner.

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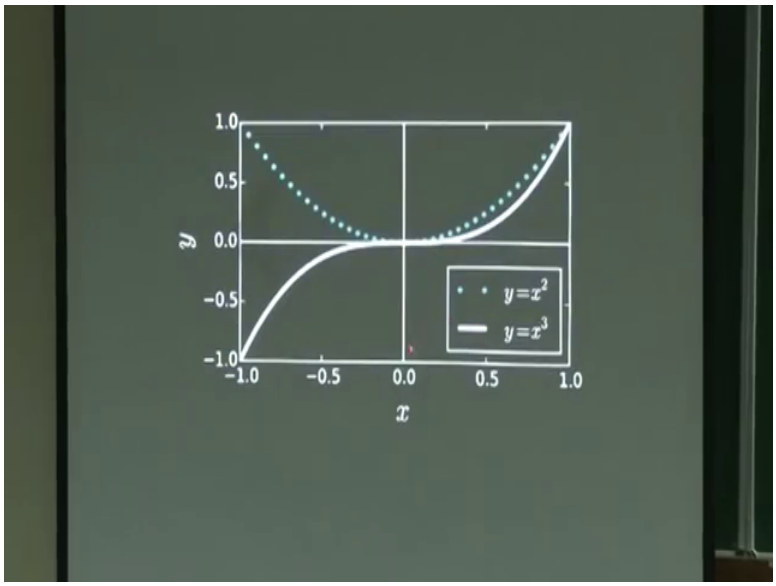

The figure looks like this it looks good, no, the figure is. So, this is dot, but I was telling you and this is that x cube and this is a legend this is called legend and this x axis label and y axis label. So, you can create this figure which is which look nice by running that command. So, if you want some different function you just change those functions and

this. So, you reuse it. So, you just see in that and reuse it. So, this for 2 d plot, now, you can do vector plots.

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So, in (Refer Time: 12:01) you have all this electric field and magnetic field. So, I am going to do a simple vector plot.

Student: (Refer Time: 12:07) where do we include the data of the (Refer Time: 12:12)

Data of the what?

Student: (Refer Time: 12:14).

[FL] where did is save it. So, I can save it. So, I was show you in the next plot. So, where do you want to save it; I will specify in the next plot; you are wanting to save PDF file.

Student: No (Refer Time: 12:27).

No, no, I did not plot from file; all the data is here. So, this x is linspace, y is x square, all the data is here, I am not importing any data. So, all the data is generated here in this 3 lines, you can import it, but I am not told you yet; how to get a data from a file. Now I want to do vector plot. So, this minus r. So, this; where does it comes; it is minus r force field. So, one who r you know; one who are r square, but where is minus r. So, my first field is minus r vector; bold means vector. So, what is minus r 2 d?

Student: (Refer Time: 13:06).

Sorry.

Student: Harmonic (Refer Time: 13:08).

Harmonic oscillator; I did in the my course last time. So, do not tell me that I did not do it. So, force is minus r is oscillator which is 2 d oscillator. I did not mention it; my belief. So, for molecule, if it attractive is minus r vector, I mean near the equilibrium point is in more than 1 dimension. So, the vector field is you plot like this. So, this part is exactly same as before. This is called color method C M; color something.

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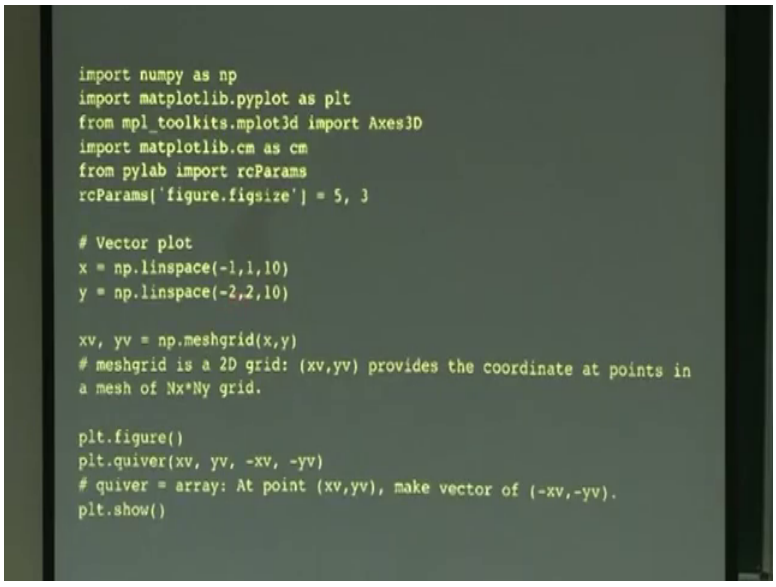

M; I forget what M is for. So, this is for color; coloring which we do not need it actually this part of something else these 2 are not required 3 d right now.

So, x data and y data; so, I need to make a grid. So, it is grid point, I will have vector you have to be careful about these 3 lines. So, my x data is from minus one to one and y data is from minus 2 to 2; 10 points each. So, 100 points per the range is different, I can choose the same range actually, I think is minus one to one I believe. So, this bit of change in my code and here, so x v and y v. So, this is obtained by mesh grid. So, these parts of numpy array any mesh grid x comma y. So, I take this x and y and create a mesh grid. So, what is x v? So, xv is a 100 by 100 point and each position will tell you the x coordinate. So, this mesh is very useful function for all plotting in a mesh; mesh is I in

this room I mesh k make a mesh like 3 d grid here 2 d grid each point I want to know what is x and what is y.

So, this is x v you can print xv and will find that for given y; all the numbers are same is xv and y v; we will give you y coordinate at that point. So, x v comma y v; we will give you at any position, it will tell you what is x and y coordinate of that point. So, this mesh grid is very commonly used in plotting not only in python, but in MATLB or even hire once for fluid solver. So, leads to dynamics.

Now, I create a figure. So, plt is starting now I am going to start using plt, so this part of matplotlib. So, this will create a figure. So, every time I knock this I create a new figure this is create a figure now this quiver is a arrow, it will create arrow at this position x comma y in the mesh. So, just imagine this; a mesh at each point.

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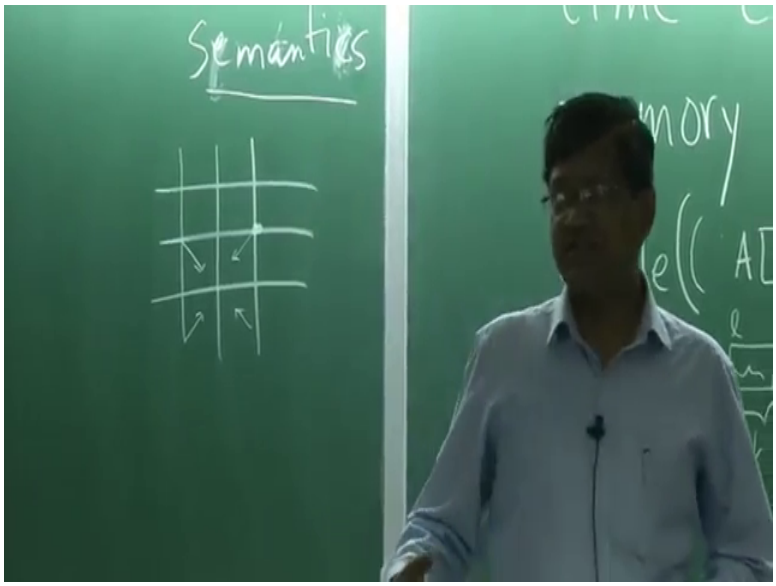

So, the first coordinate tell you; so, this is a coordinate what is the vector field at that coordinate, so the vector field here that is y. So, I am putting what. So, here the coordinate at that point is x and y; x v and y v. So, here this is just going to pi create a vector field. So, if this a origin like this.

So, this creates this arrow; arrow has x component y component. So, these are the y compo x component y component. So, these a location of the coordinate and this is a arrows components. So, it looks like this.

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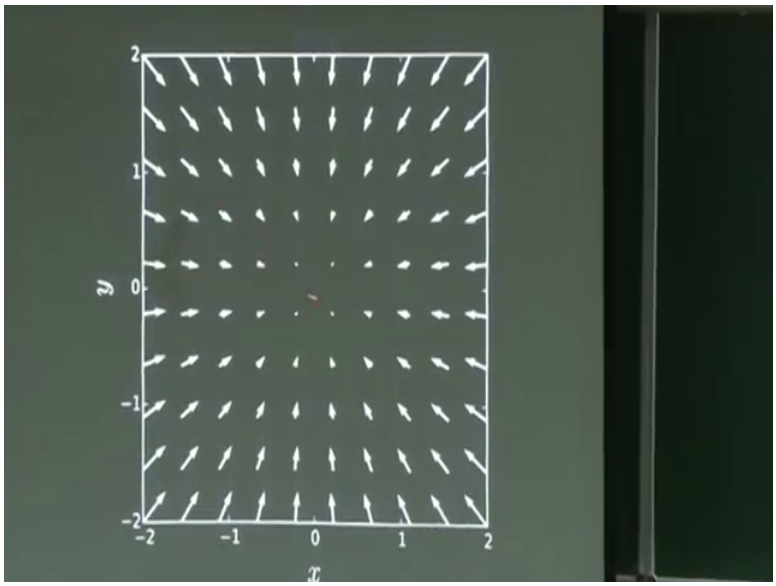

So, when you go further away; it is size is increasing and all going toward origin settings somewhere here 0 comma 0 and I solve pointing toward that this simple one, but you can create most complex vector fields.

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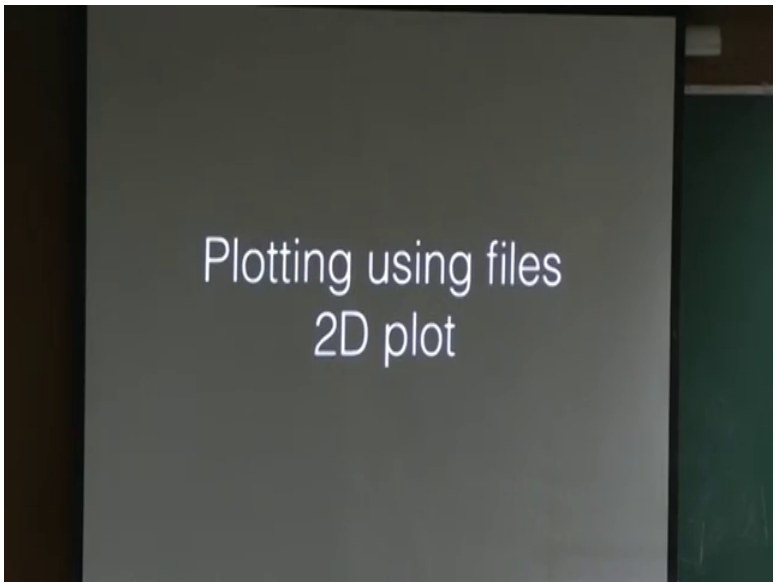

So, let us get to these plotting using files. So, when I write; when I plot for my writing research paper or for making some plots for some stuff then you have a file prepared already and you changed the functions change few things and you should you will reuse re-use it. So, that is the main idea. So, let us go through. So, this is a 2 d plot like; what I

did for x comma y 2 d is x comma y; well x is x axis and y is vertical axis. So, these are stuff which I put on the top would need numpy many times

So, I keep numpy here matplotlib. So, import as plt this again a standard you will find that this is standard practice followed plt. So, this for plot you no need to write all this just a plt; this is for getting the figure size right this is going to create a figure of 5 inch by 3 inch I want the size of the figure for my middle is my research paper or from a book not arbitrary size. So, we control the size of the figure which is easy. So, you just put it like this. So, this called parameter.

So, k this p y this are parameter of pylab. In fact, we can see what these parameters are. So, I will not get into it this 2 lines achieve this task of 5 inch by 3 inch figure now I want to plot x comma y with function as x square. So, I first create a array numpy array it minus one to one with 10 points y equal to x square and y one is x cube. So, I will plot 2 of them in same plot. So, plt dot plot x comma y. So, this is going to plot x comma y with red dots you can choose different colors.

So, you can do help of plot will find what is syntax for different color blue is byee and black is k a. So, all that I can put a label for this plot. So, if you have many plots you need to know which is corresponds to what. So, this is nice feature. So, it puts a label for. So, I will show you; when you look at the plot will find that y equal to x square corresponds to red dot it tell you that this is red dot this nice feature you will find it now the second plot x cube is x comma y one this called line width l w, you can write full line width, but python also understands that short hand; l w is 3 point. So, is thick. So, I find this thick color is green, I could have set just court code. So, I need not have put this, but there another way to wrote it label is this x cube y. So, these in latex dollar means latex x cube now this will. So, this horizontal line; so, it put a axis with color black; k is black.

Vertical line with color black now I want. So, if I do not control my limits x limit and y limit it may choose, soon I may; it may put something else of course, my plot is from minus one to one, but I want my x axis to be limited by minus one to one suppose then I say x lim; limit is minus one to one and y limit minus one to one these are optional I can put labels for the x axis and y axis. So, this is x axis and y axis font size for this size 5 inch by 3 inch this good size and I will put the legend at some location.

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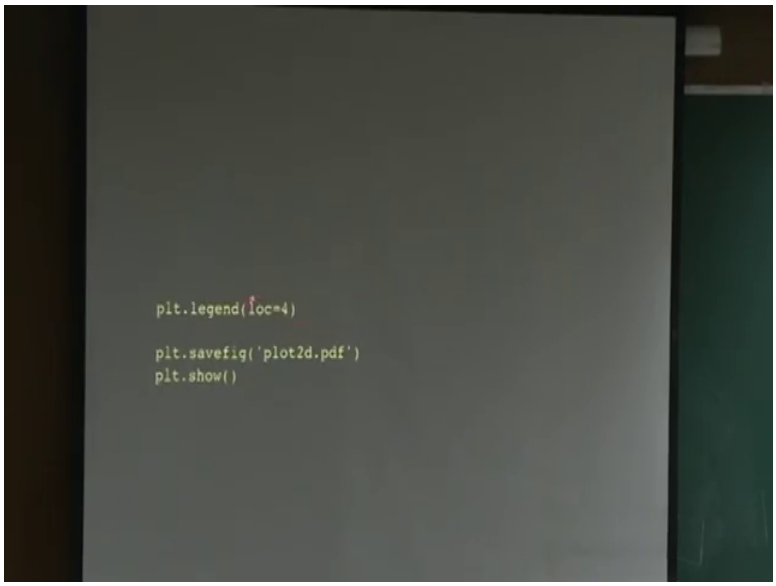

So, location 4 is means right corner. So, you can control where you want your legend to be if you do not do it then python will decide, but you can also control now I want to save it is some file. So, plt save fig; so it will do the save fig, the name of the file will be plot 2 d dot PDF, it will be in the current directory now quite a few of you are having this struggling with directory my file is not running you have to be in the right directory please do Linux; Unix tutorial which is not difficult just it will take you half a day or may be one hour for this simple stuff.

So, this plot 2 d point PDF will be present in the present directory where you are working we can of course, make you can go to some other directory by saying dot dot some other this Unix thing will understand and if I do not put this it will not show. So, it will plot it save it in that figure, but it will not show up on the screen. So, these also my output I want to see on the screen then you have to say plt dot show to show on the current graphic screen.

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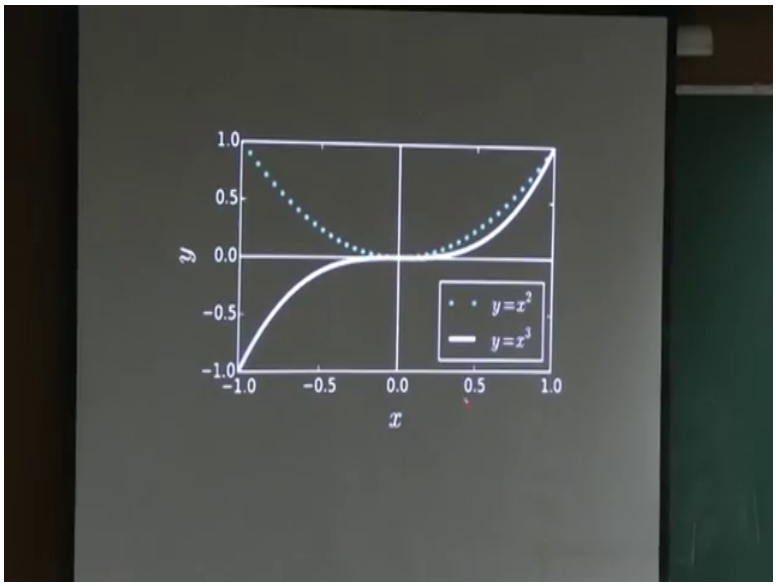

So, these will achieve the task of plotting 2 d. So, this is how the plot looks like. So, these x square and y square and you see actually now this color they not red because I converted I have inverted the color this for visualization. So, this is not exactly same as what it comes in the plot the reason of this white does not come nice in the video that is why I just converted to the black background. So, we will come with the white background, but this is been converted the background has been switched. So, this is become this is x square and this is s cube x label y label and this called legend. So, this means x square s cube. So, where it is easy and I can recycle it I want something like sinx I just need to change where one of the lines no you can add stuff. So, this can be recycle

So, now let us look at another figure vector plot is useful electro dynamics no lots of vectors. So, I want to plot minus r vector, so actually minus r cube. So, I changed it. So, r looks to trigger. So, I made it r cube. So, I must say this r cube no actually it is not r cube. So, let me just is a 2 d vector it is s cube comma y cube it is not r cube apologies.

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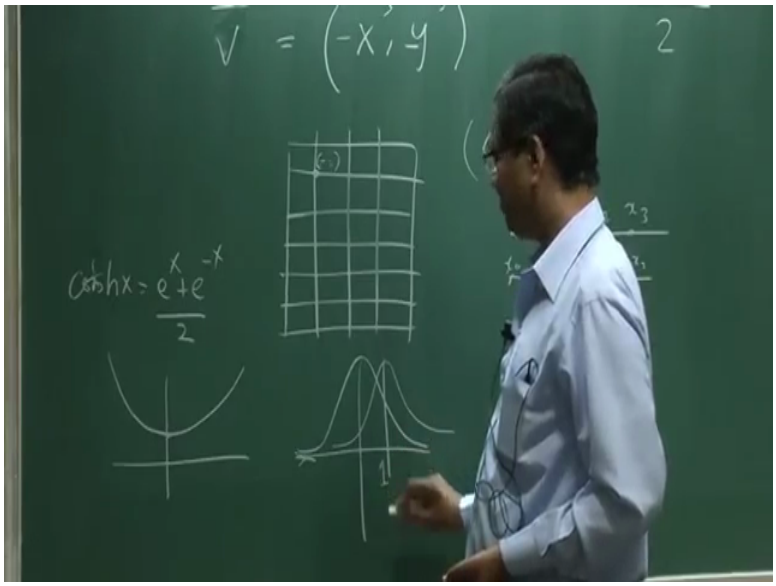

So, I am plotting vector r vector v like this. So, this might supposed somebody asked you to do this vector plot with the minus sign I thing I have minus sign here. So, let us see how to do it most of it is same I do not need these 2 lines for this figure, but again copy paste it has come I want the figure size to be 5 comma 3. Now I want to make a mesh. So, in 2 d plot for vectors we will make a mesh.

So, mesh is a grid it is just is a grid now each point corresponds to some x and y co-ordinate right and python will put a vector at that point. So, for mesh I first create. So, what is my x; x coordinates and y coordinates these are my x and y coordinates given this x and y coordinates I create a mesh grid I take this function mesh grid of numpy and create this 2 arrays x v and y v. So, this is an example of an function which gives you 2 outputs or 2 returns it returns 2 things 2 arrays. So, function can return number string arrays multiple arrays it can do lots of stuff right now it at a written 2 arrays and if you can plot rather you can look at it by just saying xv and xv is a 2 d array not one d array it is a 2 d array.

In fact, xv if you look at that array it will be suppose I want to do 4 by 4. So, the first entries will be 4 numbers which will be same x this same x sorry no no same y. So, it a same y. So, here numbers will change one this will be x 0 x one x 2 x 3 next one will be exactly same as 0 x 1, x 2, x 3, it will be 2 d mesh, but now quite a few numbers will be common. So, it is x coordinate of each point on the mesh is that clear same thing with v y

v. So, we will give you the y coordinate. So, I will again have 2 d array now this point I want coordinate then I get from xv what is this is the x is changing comma y v. So, coordinate of any point on the mesh is contained here and that is what matplotlib will use mataplotlib will use this coordinate and put some vector at each point. So, this is a nice function plt dot figure.

So, I did use it last time I did not say plt dot because of this part of pylab in the screen every time I say figure will create a new figure you do not want to be figure to be over written. So, it reads the new figure and the new new function of the matplotlib called qviver means arrow. So, make an arrow at point x v comma y v that a mesh point and what are the magnitude of coordinates x component y component of the vector. So, x component is minus x cube and y component is minus y cube. So, will create a vector at each point and I know coordinate what is coordinate x v and y v and that point. So, this is going to achieve the task of make a vector plot.

So, we will make a loop, but all that we no need to worry matplotlib will do all that. So, now, this is a standard stuff I showed in the last slide.

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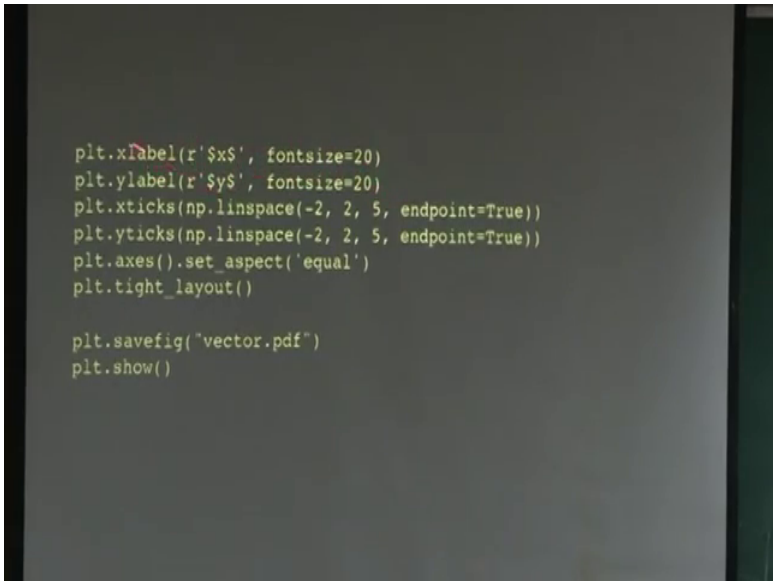

X label y label this for text I can control where should be my text to say minus 2 to 2 with 5 points 5 ticks no 5 point 5 ticks y tick can also controlled I want my aspect ratio should be equal python sometimes does not make well most of the time it does not make aspect ratio equal normally you have plots. In fact, this is stunt, this is good x axis is

always most of the time bigger no you know why it is bigger why do not you plot mostly square or like the plain cards is not square. So, why is in it square your rooms are typically not square differentiate one thing is that you will not read now a days you should read some books. In fact, you look at this plain cards or lot of stuff the ratio is supposedly the most pleasing ratio is the golden ratio; now that is hard to say it I do not have proof. So, what is golden ratio?

Student: (Refer Time: 27:25).

So, root 5 plus 1 by 2 this 1.6 something, this supposedly you could have done some experiment and these looks most pleasing. So, normally square is not will be the size of like your card shape. So, plots are not typically squares, but I want square here. So, wanted to be realistic otherwise arrows will look jacket.

So, this is that aspect ratio one figure and these are the text minus 2 minus one I want these are text you see text and these x cube minus x cube comma minus y cube these 2 contrast I mean you can make different colors; you can make it better. So, these for 2 d and 3 d will be I will make the new; next one is 3 d you can also make 3 d vector now 3 d vectors only couple of changes we need to do is a 3 d plot now. So, this is going to be minus r vector.

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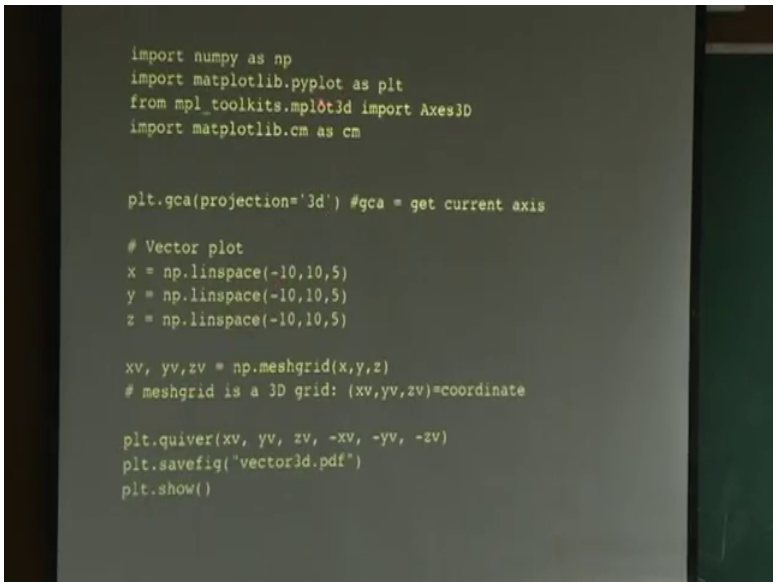

So, now I need a function is this m plot 3 d. So, this line has to be included. So, this mpl toolkit this I just copy from this is my invitation I just imitate some good programmes copy there is no shame in it I mean according to me, but it should understand what you are copying. So, this call color scheme. So, this for sometime; I will show you where I need it for his plot again I do not need it for this has been again copied from different files.

Now, this call gca there several way to do it if you are if you play around with it for a day you can do these 3 d plot in many ways one way is to declare your current access gcas get current access is position 3 d this will tell you my plot is 3 d otherwise standard is 2 d. So, here I declare that my plot will be 3 d now I create this 3 x y z arrays minus 10 to 10 only 5 points and so, this is creating a mesh now this is a 3 d mesh. So, I making in this room 3 d grid and at each point the coordinate of each point will be xv comma y v comma z v.

Now again I use the same function quiver, but since I declared it to be 3 d I have to give 3 coordinate and components of the vector 3 components of the vector and what are the 3 components of the vector these are the 3 components of the vector minus x v y v minus y v minus z v. This standard I mean of course, if you are forgetting the syntax and you can put question mark plt dot quiver in that I python window and you will find the answer I can save this figure in vector 3 d dot PDF and so, this will show if I do not put it I do not come on the screen, but I wanted on the screen. So, it will come on the screen.

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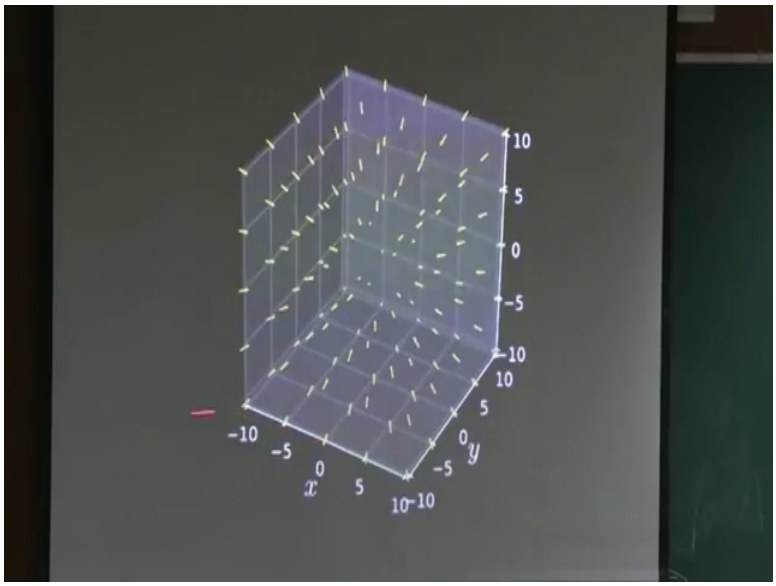

Now, how does it look plot case of the x axis y axis and z axis now this is definitely not looking very great, but. So, these are the arrows one can do better if I work very hard then I can you can also rotate this stuff this screen may be toward the end, I will show you how to rotate it, but PDF file cannot be rotated, but the file in the pylab, it can be rotated. So, 3 d stuff is nice very simple you just with the mouse you can rotate.

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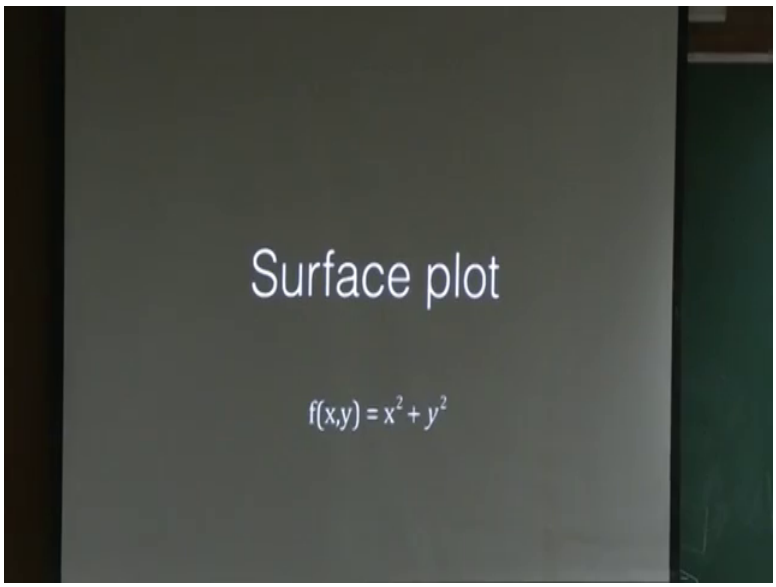

So, we can do surface plots. So, now, why do somebody do surface plot I am looking at temperature for plate no this is a plate now every point on this plate has a temperature

now want to visualize it by plotting. So, how many ways I can do it; how many ways I can I can represent the temperature in a plot.

One is contour excellent and second is surfaces you, it on the each x y, I make well basically x axis y axis and the distance along your axis give me the coordinate of the surface and there is another one what else what is that density plot. So, here I make this hot is red no and cold is blue. So, I make this picture and that is why I need color map and then I say well. In fact, is very nice just seeing the color I can see which is hot which is cold. So, these are the 3 ways you can make plot. So, a scalar field you can also extend to vector field and vector field arrows size will of course, still to the length you can make arrow colourful.

So, we can also go for vectors similar ideas, but you let us stick to surface. So, surface plot is one way to do it. So, I am just looking at 2 d if it function is 3 d. So, I am looking at temperature of this room. So, it is not possible to do surface right why is that will go in the fourth dimension on thus not possible you can take as cut of that cut you can show surface plot, but it typical used for 2 d. So, very similar to what we did. So, far this will be 3 d.

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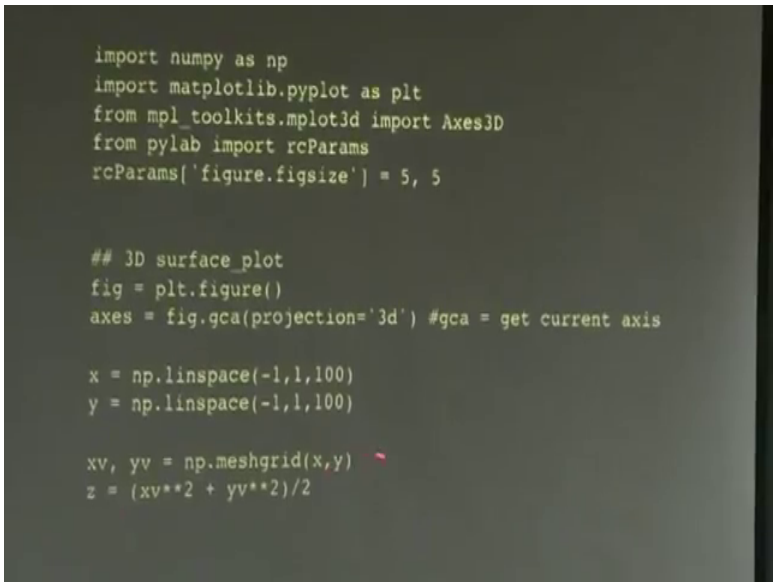

So, z axis is my temperature which is x square plus y square. So, I have to trial thus 3 d no this line will be common to what I did in the last line and I am making in my x array and y array now I create a mesh. So, this is a common step. So, you have to create a

mesh now this is that function x square plus y square by 2 now to plot it now I had to say plot surface. So, this figure has one attribute axes. So, this axes is a figure has a class any less on getting to it one variable of this figure which is has property of that axes. So, the is also important variable if you look at my slides and you read up little bit more then you will understand.

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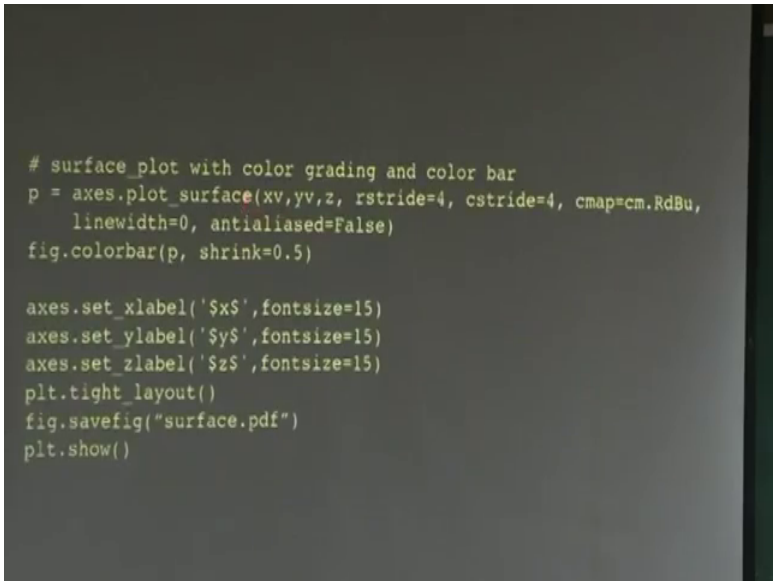

So, here I am saying axes dot plot surface some time you get an error. So, this function is belongs to access variable.

So, these are layers of objects. So, like I want to go to house I have to go to first inside IIT, than take a street then another smaller street. So, this is how you can think of loosely. So, this is plot surface part of this axes and I do just say x v x y comma z. So, it has 3 variables this is x coordinate y coordinate and z is a vertical coordinate now this part I just copied. So, this color scheme, color bar show you the color bar different color mean different values, so x label y label z label. So now, this is also nice sometimes I will show you what this tight layout means this is useful and I am saving enough figure in saving in a file. So, the figure looks like this.

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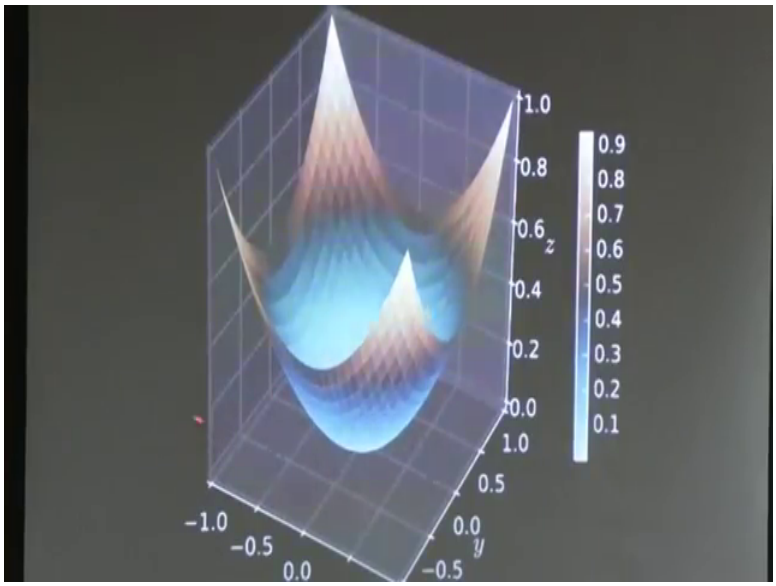

So, it also has a color this is lowest blue and yellow is highest, it is not very useful here because from the surface I know which is high temperature and which is low temperature, but it will useful in the next couple of slides. So, this x axis y axis and this is z axis. So, labels also here sometimes when I save it the x will get cut. So, it kind of exceeds of it go outside the window. So, the tight layout the function which I showed you this is useful you just puts in the appropriate window. So, this gives you better figure. So, these surface plots now want to make control plot of the same thing.

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So, well is this the different function minus log square root of x square plus y square. So, x array y array this my function z now I can do like this curves equal to plt dot control now how many control do I want I can control here I want 6 controls. So, I want 10 lines I can increase the number here now I can also put color bar. So, different controls mean different thing. So, you can also put values of the control I have not done it here, but you can also easily find how to put values of the control now rest all is same. So, let is look at it.

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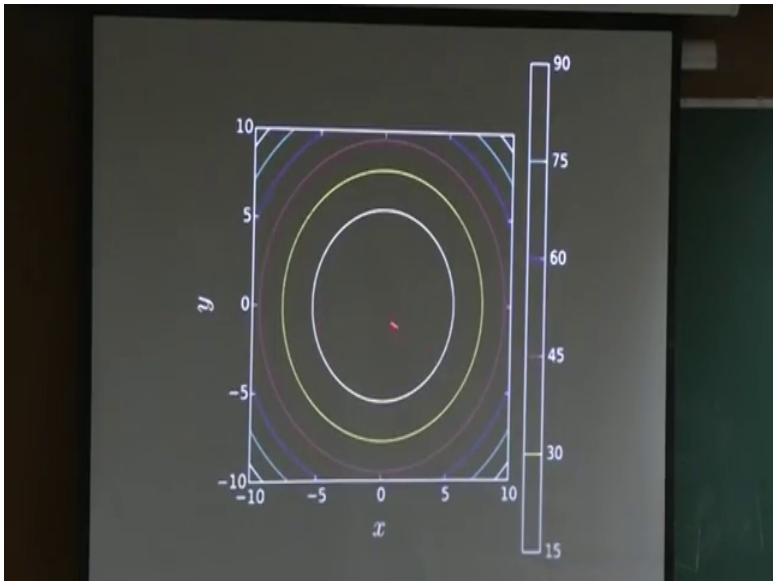

So, this control plot lowest is fifteen here now computer choosing by its own, I can also control I want control. So, or these values of that variables you can control it, but I did not controlled here. So, computer will decide fifteen to ninety now this corresponds to fifteen this corresponds to 30-45 is doing like that next is density plot. So, I just said different colors will mean different values different strength of the function now 2 ways to do density plot. So, all of it one thing is common is called mesh you have to make the mesh.

So, this mesh create the. So, this part is common now I am making the figure size all that is common now this called im so ims how. So, this will plot z now this is putting the minimum and maximum to this whole thing is one line from here till here. So, this will take care of plotting z it is a 2 d plot. So, it will plot in that mesh and while plt also color

bar showing the strength of the function and this is x axis y axis. So, this is same as before. So, this one way to do it in another way to do is called function p color.

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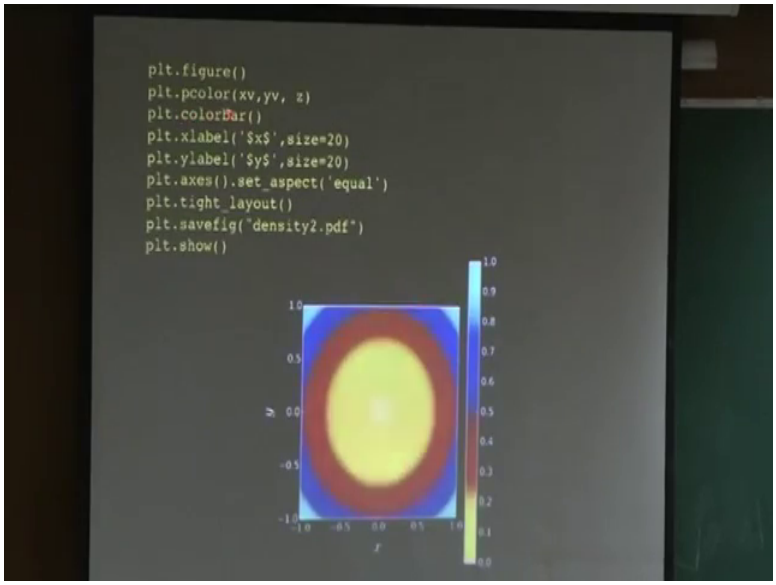

So, we can also plot density plot by using p color case; x coordinate y coordinate and z coordinate value of the function at x comma y its not a z coordinate is the value of the function. So, this is called color bar, now lowest is 0 its increasing you know I mean I cannot say everything is 0 increasing. So, is increases slowly. So, it reaches up to point 2 somewhere here then it has reach point 5 here and it is gone up to one somewhere. So, these how we can make a density plot. So, lot of scalar feels in represent within nicely with it. So, I have made 2 files this is only the p color I think this is in p color you can make with mesh as well as p color.

One of them I am not sure which one looks better. So, I have a; you just play around with it. So, we can make animation.

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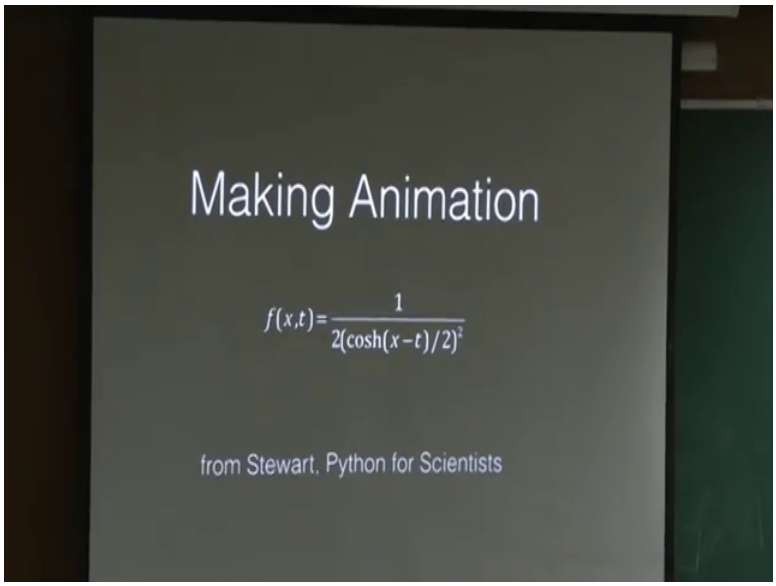

So we can also make particle trajectories in 3 d. So, that I may give as homework I think is no actually I cannot give as homework is already there you can make a particle trajectory. So, is again will be using axes 3 d. So, helical trajectory is drawn I may have it somewhere later you can make nice animation. So, I want this copied from Stewart is a nice book is does assume that you know bit of programming. So, this python for scientist I want to plot these function different times. So, I will plot f of x at different times and it will move. So, you will see there it will move. So, how does the function looks like call given time, let us say t equal to 0. So, how does cos hyperbolic. So, cos hyperbolic 0 is you know everyone know what cos hyperbolic know cos hyperbolic x is equal x 2.

So, x equal to 0 is one and it increases. So, it is one. So, for large x will increases because of this and small x will increases because of this is a even function now inverting it. So, it will be it will be this becomes 0. So, I is a positive value. So, square it looks like Goshen in. So, at a different time; so, at if the increase t it will become 0 at maximum at that value of x. So, these going to shift these for d equal to 0 now t equal to one what happens to that it moves to the right same function this will corresponds to x equal to one this just shifts.

So, it is easy to write this code.

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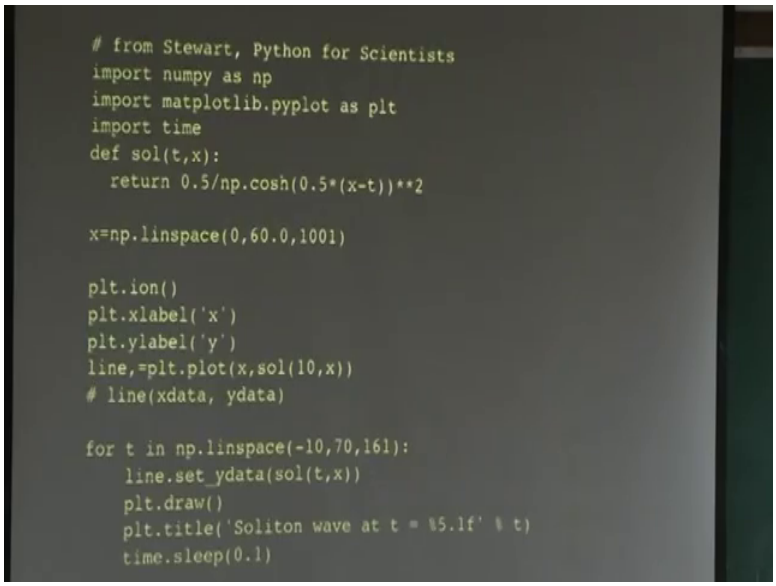

So, these are function solution p comma x now I use one property of this function called of plt it also written something is line colon there is other aspect which he we do not want it is written quite a few things if I do not put comma it will complain. So, there are other values written, but you no need to worry about this how many does written I do not know, but i. So, line contains x data and y data. So, every plot has x data nad y data right while it has created itself plot, but matlib will not allow you to this stuff you know here again easily get this features matdotlib will tell you what all is doing x data is fixed x data is here 0 to 60 is 1000; one point.

Now when I do this execute this function I get x data will remain same, but my y data will change it different times t equal to 0 it is this led time is this. So, my y data; so, value of y at every x is changing in different times and that is what I need to feed it feed in; so 40 in range minus 10 to 70. So, I am running from time from minus 10 to 70 and how many steps one sixty one steps and I said the y data from this function at that time. So, these a key feature. So, am basically using these function and I said the y data and you say use draw will draw at that time they also put the title and this sleep means it will not do anything it will just sleep point one second.

However, it could be too fast the computer will just move very quickly and you will not able to see this line move this plot move this just move too fast.

So, let us I will I will lets run this one.

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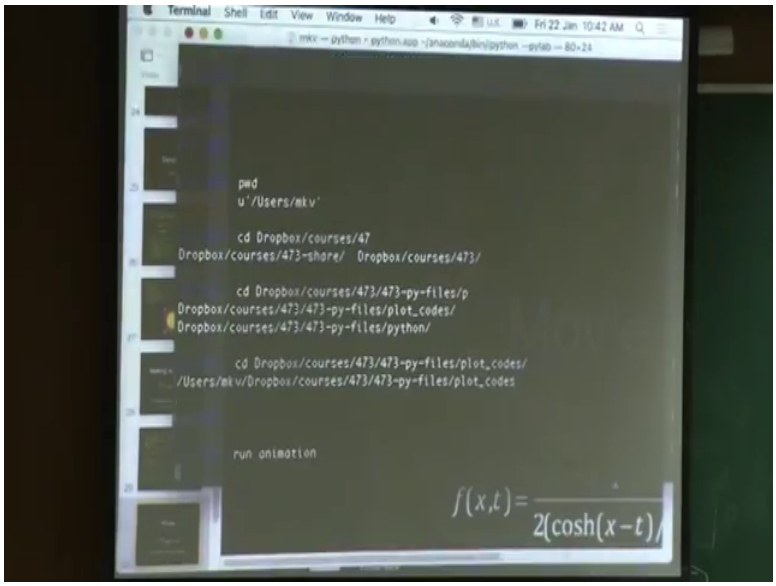

So, this is where I am in the wrong directory. So, I have to go to the right directory. So, run animation this exactly same code I just run it. So, a. So, point 2; one I had seen this one let us point one and this run it again. So, let us give the figure file its coming from the left its just moving. So, let us quickly finish the second one you can make a movie here I cannot save it as a what format do use for movies; so, many formats. So, one mpeg is one of the popular format. So, save in mpeg then you can run it later. So, to run a make a movie this part is straight forward know.

So, I just this new function got draw frame and same each frame. So, in the movie you know they just statics pictures which are run fast not too fast not too slow at least 30 frame per second right. So, this is an a loop I will go from minus 10 to 10 with 101 frames these number of frames. So, this part we have to be careful file name file name means temp now here I am going to put my name of the index of the frame. So, we will create lot of temp files and will just pieces together each file will contain the one plot if there exactly what movie makers do and they just take lot of pictures and they pieces together and draw frame draw frame will plot it.

So, this will make 1 plot and will save it and where does it save it save in that the file. So, when I loop it I create lot of temp files each temp file has a index you can impact you can run this programmes and when you look at the directory you will get all these files temp 0 0 1 dot png this called png format; it takes less space and you will create there

Now to this will create lot of files now I want to merge them together in a single mpeg video.

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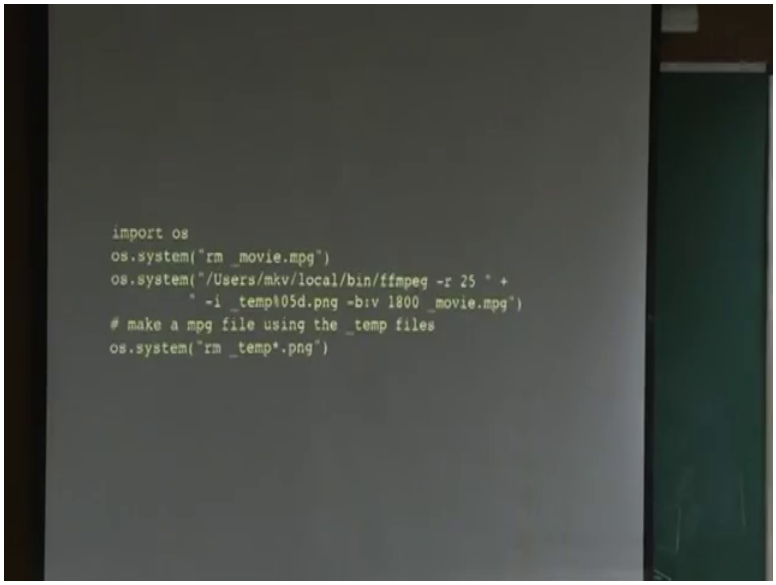

So, now I need to use some other package. So, idea is to import operate. So, basically you start you run this function you can run it from outside, but you can also run it from within python. So, after those files are made. So, this is not part of python you have to download this package ffmpeg; you will piece it together.

So, all these are part of system nothing rule python, but you can run with in the python. So, when I say import os, it is import operating system while is not importing everything whatever it need it will access too. So, first if the file exist movie dot png, it will remove it old file, remove it, then it is going to call this function. So, I have to give the path. So, is this; my file is in this path and this file this index I copied. So, it will put the speed how fastly move all that stuff will be here you can control it, but I did not do anything.

So, these the file all that file it will file names and it will make a new file called movie dot mpeg and it will remove the temp files we do not need the temp files we removes it lets quickly run it. So, well running is. So, if I just run it a movie now I will run the movie instead of inside is right here. So, it is created by this.

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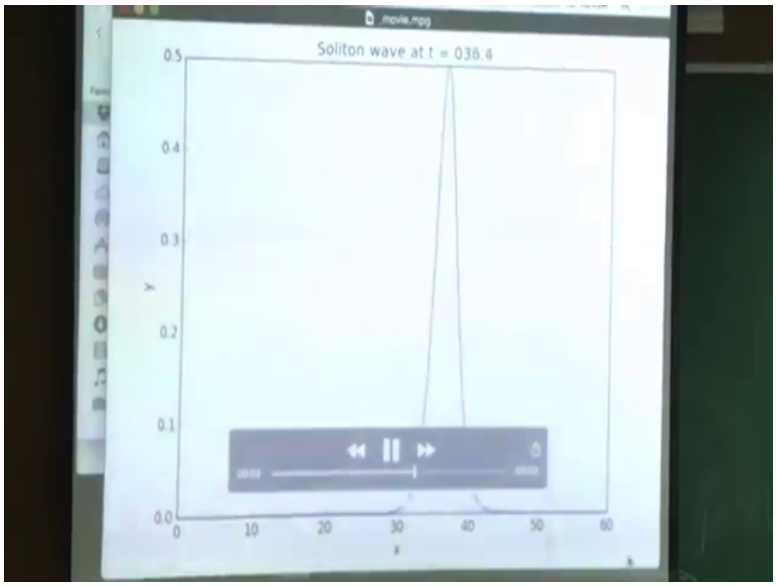

So, we can replay it that sums up what all we can do you can do lots of stuff. So, if you look at matplotlib has a very nice website and it has lots of example you can do scattered plot you can make arrows you can leave it can do tones of things. So, I shared all of it plot 3 d plot 3 d plot 3 d. So, this makes this helical path, so this practical in the magnical key. So, I am going to use basically x comma y comma z, but I am using this x s 3 d this is a function this is what is going to achieve. So, it exactly same thing what did for vector 3 d, but I am plotting not in a mesh, but I am plotting xyz.

So, if you run this one and I can rotate this one know I have time. So, this just by the mouse this is trivial.

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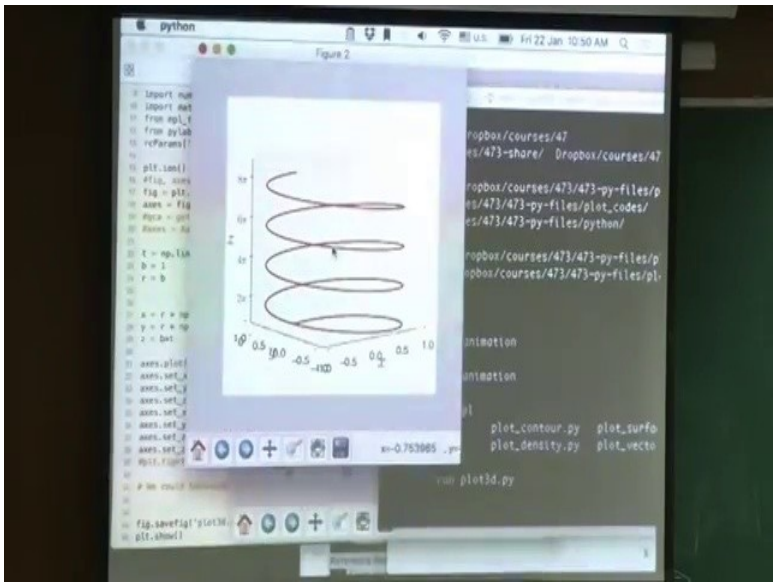

But sometimes you want to see from different angles you can also zoom it by zoom in now. So, these a right click and left click that is it nothing else. So, it is very very nice.