Talking Physics
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Getting Started Animating with manim and Python 3.7

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I previously wrote a series of blog posts detailing how to use manim, the **m**athematical **anim**ation package created by Grant Sanderson of 3Blue1Brown. Since I've written those posts there have been many changes to manim, including switching to Python 3.7. I will go through and update my information for the version of manim as of December, 2018. Much of the information will be a repeat of earlier posts in situations where there have been no changes to the manim code. The primary changes from my previous series of posts are related to changes to manim, primarily in dealing with 3D scenes. Note that future versions may break some of these commands, but hunting down the problems is the best way to learn the inner workings of manim.

1.0 Installing manim

Brian Howell has put together a really nice post on how to install the necessary components of manim at http://bhowell4.com/manic-install-tutorial-for-mac/. One of the most useful tips for making sure everything works is to use virtual environments. If you have trouble getting manim working I suggest asking for help on the github page for manim since that has an active group of users who can typically help out.

The Readme docs on github also have instructions on installing manim.

To make sure you installation is working you can run the example file that comes with manim. Type `python -m manim example_scenes.py -pl`. If this produces errors you should check out the Issues tab on the github site since frequently someone else has had the same issue.

2.0 Creating Your First Scene

You can copy and paste the code below into a new text file and save it as `manim_tutorial_P37.py` in the top-level manim directory or you can download all of the tutorials at https://github.com/zimmermant/manim_tutorial/blob/master/manim_tutorial_P37.py. The `.py` extension tells your operating system that this is a Python file.

Open up a command line window and go to the top-level manim directory, and type `python -m manim pymanim_tutorial_P37.py Shapes -pl`

We are calling the Python interpreter with the `python` command. If you have multiple versions of Python installed you may need to call `python3` rather than just `python` (I use Anaconda virtual environments to keep all manim-related Python code in one handy place).

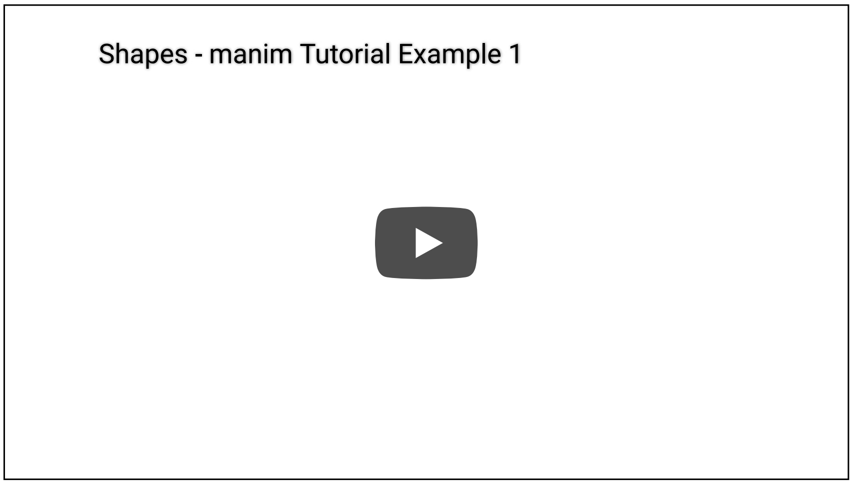
The first argument passed to Python, `manim` is running [manim.py]() in the main manim directory (we'll ignore the `-m` switch, which you should include). It looks like you can live-stream the output to Twitch but I'm not using that feature so I'll focus on [extract_scene.py](), which is called from manim.py and which is the code that runs your script and creates a video file. The second argument, `manim_tutorial_P37.py` is the name of the file (i.e. the module) where your script is stored. The third argument, `Shapes` is the name of the class (i.e. the scene name) defined within your file that gives instructions on how to construct a scene. The last arguments, `-pl` tell the `extract_scene` script to **p**review the animation by playing it once it is done and to render the animation in **l**ow quality, which speeds up the time to create the animation. Typing `python -m manim --help` will pull up a list of the different arguments you can use when calling `python -m manim`.

```
from big_ol_pile_of_manim_imports import *

class Shapes(Scene):
    #A few simple shapes
    def construct(self):
        circle = Circle()
        square = Square()
        line=Line(np.array([3,0,0]),np.array([5,0,0]))
        triangle=Polygon(np.array([0,0,0]),np.array([1,1,0]),np.array([1,-1,0]))

        self.add(line)
        self.play(ShowCreation(circle))
        self.play(FadeOut(circle))
        self.play(GrowFromCenter(square))
        self.play(Transform(square,triangle))
```

If everything works you should see the following messages (or something similar) in your terminal:

The first line in the command terminal tells you where the video file is being saved. The next several lines list the name of the animation commands that you called, along with some information about how long it took for each animation and other info I don't understand. The last line just lets you know how many animations were called in your script.

The video should look like this:



All of the various manim modules are contained in `big_ol_pile_of_manim_imports.py` so importing this gives you all of the basic features of manim. This doesn't include every single module from manim but it contains the core modules. You can look at the modules included here. It is worth your time to dive into some of the modules to see how things are put together. I've learned a surprising amount of Python by trying to figure out how things work. Incidentally I find using the search box at https://github.com/3b1b/manim very helpful for finding different classes and figuring out what arguments they take and how they work. Documentation is also being put together for manim here, although it is still a work in progress.

2.1 Scenes and Animation

The `Scene` is the script that tells manim how to place and animate your objects on the screen. I read that each 3blue1brown video is created as individual scenes which are stitched together using video editing software. You must define each scene as a separate class that is a subclass of `Scene`. This class must have a `construct()` method, along with any other code required for creating objects, adding them to the screen, and animating them. The `construct()` method is essentially the main method in the class that gets called when run through `extract_scene.py` (which is called by the manim.py script). It is similar to `__init__`; it is the method that is automatically called when you create an instance of any subclass of `Scene`. Within this method you should define all of your objects, any code needed to control the objects, and code to place the objects onscreen and animate them.

For this first scene we've created a circle, a square, a line, and a triangle. Note that the coordinates are specified using numpy arrays `np.array()`. You can pass a 3-tuple like `(3,0,0)`, which works sometimes, but some of the transformation methods expect the coordinates to be a numpy array.

One of the more important methods from the `Scene()` class is the `play()` method. `play()` is what processes the various animations you ask manim to perform. My favorite animation is `Transform`, which does a spectacular job of morphing one math object (a **mobject**) into another. This scene shows a square changing into a triangle, but you can use the transform to morph any two objects together. To have objects appear on the screen without any animation you can use `add()` to place them. The line has been added and shows up in the very first frame, while the other objects either fade in or grow. The naming of the transformations is pretty straight forward so it's usually obvious what each one does.

Things to try

– Change the order of the `add()` and `play()` commands. How does changing the order affect when they appear on the

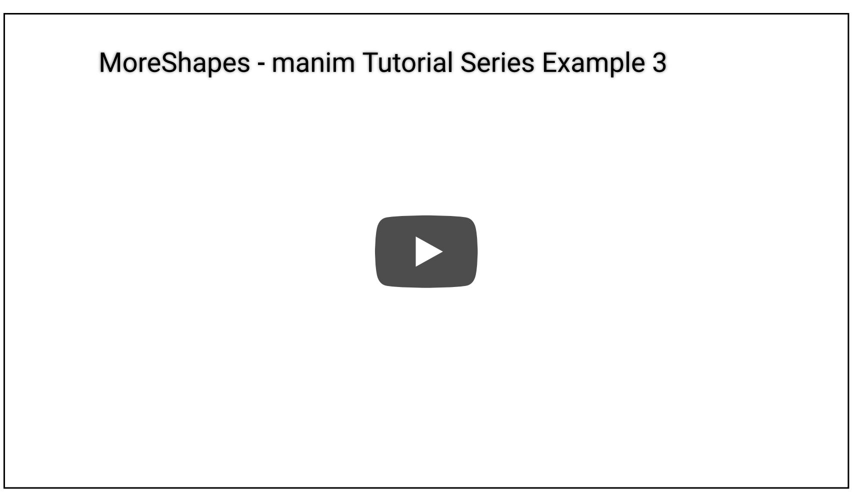
screen.
– Try using the `Transform()` method on other shapes.
– Check out the shapes defined in geometry.py which is located in the `/manim/manimlib/mobject/` folder.

3.0 More Shapes

You can create almost any geometric shape using manim. You can create circles, squares, rectangles, ellipses, lines, and arrows. Let's take a look at how to draw some of those shapes.

You can download the completed code here: manim_tutorial_P37.py. After downloading the tutorial file to your top level manim directory you can type the following into the command line to run this scene: `python -m manim manim_tutorial_P37.py MoreShapes -pl`.

```
class MoreShapes(Scene):
    def construct(self):
        circle = Circle(color=PURPLE_A)
        square = Square(fill_color=GOLD_B, fill_opacity=1, color=GOLD_A)
        square.move_to(UP+LEFT)
        circle.surround(square)
        rectangle = Rectangle(height=2, width=3)
        ellipse=Ellipse(width=3, height=1, color=RED)
        ellipse.shift(2*DOWN+2*RIGHT)
        pointer = CurvedArrow(2*RIGHT,5*RIGHT,color=MAROON_C)
        arrow = Arrow(LEFT,UP)
        arrow.next_to(circle,DOWN+LEFT)
        rectangle.next_to(arrow,DOWN+LEFT)
        ring=Annulus(inner_radius=.5, outer_radius=1, color=BLUE)
        ring.next_to(ellipse, RIGHT)

        self.add(pointer)
        self.play(FadeIn(square))
        self.play(Rotating(square),FadeIn(circle))
        self.play(GrowArrow(arrow))
        self.play(GrowFromCenter(rectangle), GrowFromCenter(ellipse), GrowFromCenter(ring))
```



You'll notice we have a few new shapes and we are using a couple of new commands. Previously we saw the `Circle`, `Square`, `Line`, and `Polygon` classes. Now we've added `Rectangle`, `Ellipse`, `Annulus`, `Arrow`, and `CurvedArrow`. All shapes, with the exception of lines and arrows, are created at the origin (center of the screen, which is (0,0,0)). For the lines and arrows you need to specify the location of the two ends.

For starters, we've specified a color for the square using the keyword argument `color=`. Most of the shapes are subclasses of [VMobject](), which stands for a **v**ectorized **m**ath **object**. `VMobject` is itself a subclass of the **m**ath **object** class [`Mobject`](). The best way to determine the keyword arguments you can pass to the classes are to take a look at the allowed arguments for the VMobject and Mobject class. Some possible keywords include `radius`, `height`, `width`, `color`, `fill_color`, and `fill_opacity`. For the `Annulus` class we have `inner_radius` and `outer_radius` for keyword arguments.

A list of the named colors can be found in the `COLOR_MAP` dictionary located in the [constant.py]() file which is located in the `/manim/manimlib/` directory. The named colors are keys to the `COLOR_MAP` dictionary which yield the hex color code. You can create your own colors using a [hex color code picker]() and adding entries to `COLOR_MAP`.

3.1 Direction Vectors

The [constants.py]() file contains other useful defintions, such as direction vectors that can be used to place objects in the scene. For example, `UP` is a numpy array (0,1,0), which corresponds to 1 unit of distance. To honor the naming convention used in manim I've decided to call the units of distance the MUnit or **m**ath **unit** (this is my own term, not a manim term). Thus the default screen height is 8 MUnits (as defined in [constants.py]()). The default screen width is 14.2 MUnits.

If we are thinking in terms of x-, y-, and z-coordinates, `UP` is a vector pointing along the positive y-axis. `RIGHT` is the array (1,0,0) or a vector pointing along the positive x-axis. The other direction vectors are `LEFT`, `DOWN`, `IN`, and `OUT`. Each vector has a length of 1 MUnit. After creating an instance of an object you can use the `.move_to()` method to move the object to a specific location on the screen. Notice that the direction vectors can be added together (such as `UP+LEFT`) or multiplied by a scalar to scale it up (like `2*RIGHT`). In other words, the direction vectors act like you would expect mathematical vectors to behave. If you want to specify your own vectors, they will need to be numpy arrays with three components. The center edge of each screen side is also defined by vectors `TOP`, `BOTTOM`, `LEFT_SIDE`, and `RIGHT_SIDE`.

The overall scale of the vectors (the relationship between pixels and MUnits) is set by the `FRAME_HEIGHT` variable defined in [constants.py](). The default value for this is 8. This means you would have to move an object `8*UP` to go from the bottom of the screen to the top of the screen. At this time I don't see a way to change it other than by changing it in `constants.py`.

Mobjects can also be located relative to another object using the `next_to()` method. The command `arrow.next_to(circle,DOWN+LEFT)` places the arrow one MUnit down and one to the left of the circle. The rectangle is then located one MUnit down and one left of the arrow.

The `Circle` class has a `surround()` method that allows you to create a circle that completely encloses another mobject. The size of the circle will be determined by the largest dimension of the mobject surrounded.

3.2 Making Simple Animations

As previously mentioned, the `.add()` method places a mobject on screen at the start of the scene. The `.play()` method can be used animate things in your scene.

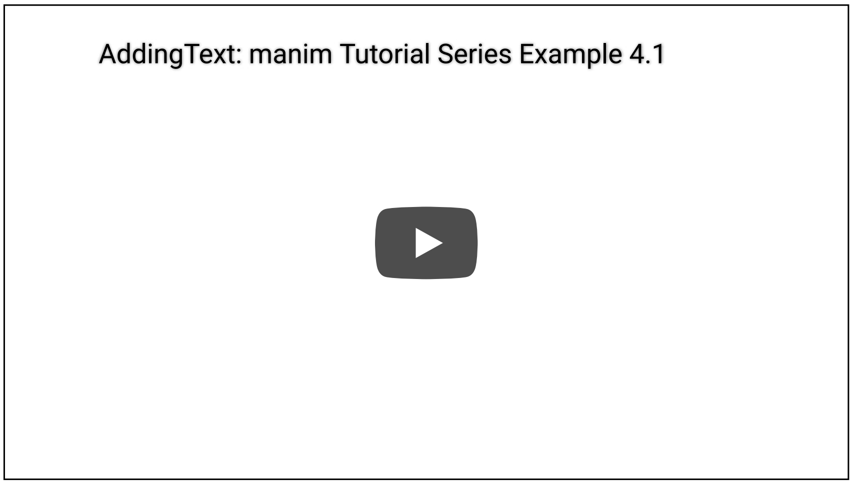
The names of the animations, such as `FadeIn` or `GrowFromCenter`, are pretty self-explanatory. What you should notice is that animations play sequentially in the order listed and that if you want multiple animations to occur simultaneously, you should include all those animations in the argument of a single `.play()` command separated by commas. I'll show you how to use lists of animations to play multiple animations at the same time later.

Things to try:
– Use the `Polygon` class to create other shapes
– Try placing multiple objects on the screen at various locations using `next_to()` and `move_to()`
– Use `surround()` to draw a circle around objects on the screen
– Take a look at the different types of transformations available in [/manim/manimlib/animation/transforms.py]

4.0 Creating Text

There is a special subclass of Mobject called a TextMobject (a **text m**ath **object**) that can be found in tex_mobject.py. Type `python -m manim manim_tutorial_P37.py AddingText -pl` at the command line. Note that the text looks really fuzzy because we are rending the animations at low quality to speed things up. With a small file like this you could render it at full resolution without taking too much time. To do this, replace `-pl` with `-p` (leaving off the **l**ow resolution tag).

```
class AddingText(Scene):
    #Adding text on the screen
    def construct(self):
        my_first_text=TextMobject("Writing with manim is fun")
        second_line=TextMobject("and easy to do!")
        second_line.next_to(my_first_text,DOWN)
        third_line=TextMobject("for me and you!")
        third_line.next_to(my_first_text,DOWN)

        self.add(my_first_text, second_line)
        self.wait(2)
        self.play(Transform(second_line,third_line))
        self.wait(2)
        second_line.shift(3*DOWN)
        self.play(ApplyMethod(my_first_text.shift,3*UP))
```



To create a textmobject you must pass it a valid string as an argument. Text rendering is based on Latex so you can use many Latex typesetting features; I'll get into that later. As a subclass of Mobjects, any method such as `move_to()`, `shift()`, and `next_to()` can be used with textmobjects.

The `wait()` method will prevent the next command for the scene from being executed for the desired number of seconds. The default time is 1 second so calling `self.wait()` will wait 1 second before executing the next command in your script.

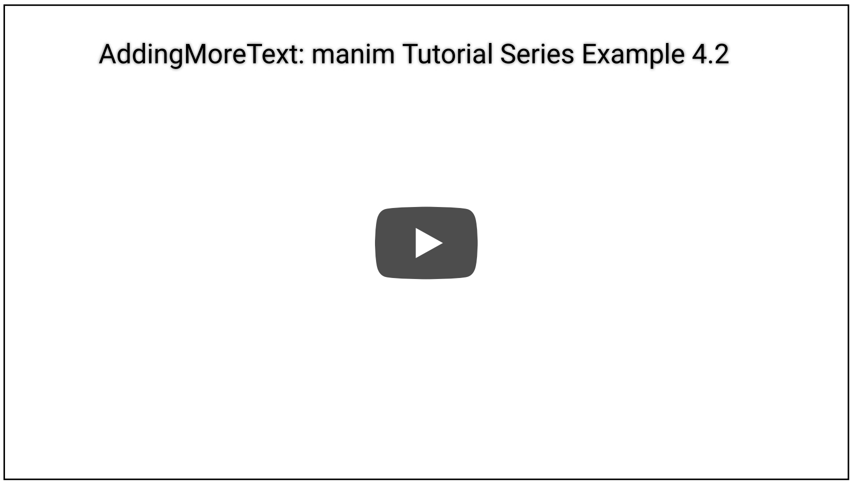
You should notice that, during the animation, the second line jumps down while the top line gently glides up. This has to do with the fact that we applied the `shift()` method to the second line but we created an animation of the shift to the first line. When animating a `mobject()` method (like `shift()`, `next_to()` or `move_to()`), the `ApplyMethod()` animation is needed inside of a `play()` command. The `shift()` method by itself moves the mobject while using `ApplyMethod()` will animate the motion between the starting and ending points. Notice the arguments of `ApplyMethod()` is a pointer to the method (in this case `my_first_text.shift` without any parentheses) followed by a comma and then the what you would normally include as the argument to the `shift()` method. In other words, `ApplyMethod(my_first_text.shift,3*UP)` will create an animation of shifting `my_first_text` three MUnits up.

4.1 Changing Text

Try running the `AddMoreText` scene.

```
class AddingMoreText(Scene):
    #Playing around with text properties
    def construct(self):
        quote = TextMobject("Imagination is more important than knowledge")
        quote.set_color(RED)
        quote.to_edge(UP)
        quote2 = TextMobject("A person who never made a mistake never tried anything new")
        quote2.set_color(YELLOW)
        author=TextMobject("-Albert Einstein")
        author.scale(0.75)
        author.next_to(quote.get_corner(DOWN+RIGHT),DOWN)

        self.add(quote)
        self.add(author)
        self.wait(2)
        self.play(Transform(quote,quote2),
```

```
          ApplyMethod(author.move_to,quote2.get_corner(DOWN+RIGHT)+DOWN+2*LEFT))

        self.play(ApplyMethod(author.scale,1.5))
        author.match_color(quote2)
        self.play(FadeOut(quote))
```



Here we see how to change the color of text using `set_color()`. This uses the same colors discussed in relation to drawing geometric shapes, many of which are defined in the `COLOR_MAP` dictionary in [`constants.py`](). In addition to setting the color, you can also match the color to another object. In the second to last line of code above we use `match_color()` to change the color of the `author` to match `quote2`.

You can change the size of text using `scale()`. This method scales the mobject up by the numerical factor given. Thus `scale(2)` will double the size of a mobject while `scale(0.3)` will shrink the mobject down to 30% of its current size.

You can align mobjects with the center of the edge of the screen by telling `to_edge()` whether you want the object to be `UP`, `DOWN`, `LEFT`, or `RIGHT`. You can also use `to_corner()`, in which case you need to combine two directions such as `UP+LEFT` to indicate the corner.

Each mobject has a bounding box that indicates the outermost edges of the mobject and you can get the coordinates of the corners of this bounding box using `get_corner()` and specifying a direction. Thus `get_corner(DOWN+LEFT)` will return the location of the lower left corner of a mobject. In our example we find the lower right corner of `quote` and place the author one unit down from that point. Later we move the `author` down and slightly left of `quote2`.

An important thing to note is that the `Transform()` animation still leaves the mobject `quote` on the screen but has just changed its display text and properties to be those of `quote2`. This is why `FadeOut()` refers to `quote` and not `quote2`. However, the corner of `quote` is where it was originally, which is why we have to find the corner of `quote2` to move `author` to the correct location. Keep in mind that when you use `Tranform`, properties of the mobects involved might not be what you think they are so user beware.

Another useful piece of information is that the `scale()` method changes the size of the objects as it currently is. In other words, using `scale(.5)` followed by `scale(.25)` results in an object that is $0.5 * 0.25 = 0.125$ times the original size and not 0.25 as you might think.

Things to try:
– Compare using `.shift()`, `next_to()`, and `move_to()` to applying them with the `ApplyMethod()` method
– Try using the `to_corner()` method
– Check out `COLOR_MAP` in the [constants.py]() file and change the color of the text

4.2 Rotating and Highlighting Text

The following code will demonstrate how to rotate text and give it some pizzazz. Go ahead and run `python -m manim manim_tutorial_P37.py RotateAndHighlight -p`

```
class RotateAndHighlight(Scene):
    #Rotation of text and highlighting with surrounding geometries
    def construct(self):
        square=Square(side_length=5,fill_color=YELLOW, fill_opacity=1)
        label=TextMobject("Text at an angle")
        label.bg=BackgroundRectangle(label,fill_opacity=1)
        label_group=VGroup(label.bg,label)  #Order matters
        label_group.rotate(TAU/8)
        label2=TextMobject("Boxed text",color=BLACK)
        label2.bg=SurroundingRectangle(label2,color=BLUE,fill_color=RED, fill_opacity=.5)
        label2_group=VGroup(label2,label2.bg)
        label2_group.next_to(label_group,DOWN)
        label3=TextMobject("Rainbow")
        label3.scale(2)
        label3.set_color_by_gradient(RED, ORANGE, YELLOW, GREEN, BLUE, PURPLE)
        label3.to_edge(DOWN)

        self.add(square)
        self.play(FadeIn(label_group))
        self.play(FadeIn(label2_group))
        self.play(FadeIn(label3))
```

We've added a square in the background to show what `BackgroundRectangle` does. Note that the opacity of the fill color defaults to zero so if you don't define the `fill_opacity` you only see the edges of the square. To create a background rectangle you need to specify the textmobject to apply this method to, as well as the opacity. You can't change the color background to anything but black.

The `VGroup` class allows you to combine multiple mobjects into a single vectorized math object. This allows you to apply any `VMobject` methods to the all elements of the group. You are still able change properties of the original mobjects after they are added to a group. In other words, the original mobjects are not destroyed, the vmobject is just a higher level grouping of the mobjects. By grouping the text and the background rectangle we can then use `rotate()` to change the orientation of both objects together. Note that `TAU` is equal to 2π (see [the Tau Manifesto](), which makes some interesting points).

The `next_to()` method can be thought of as a shift relative to some other object so `label2_group.next_to(label_group,DOWN)` places `label2_group` shifted down one unit from `label1_group` (remember that the unit of distance is set by the `FRAME_HEIGHT` variable in `constants.py` and the default screen height is 8 units).

You can create a a color gradient using `set_color_by_gradient()`. Pass the method any number of colors, separated by commas.

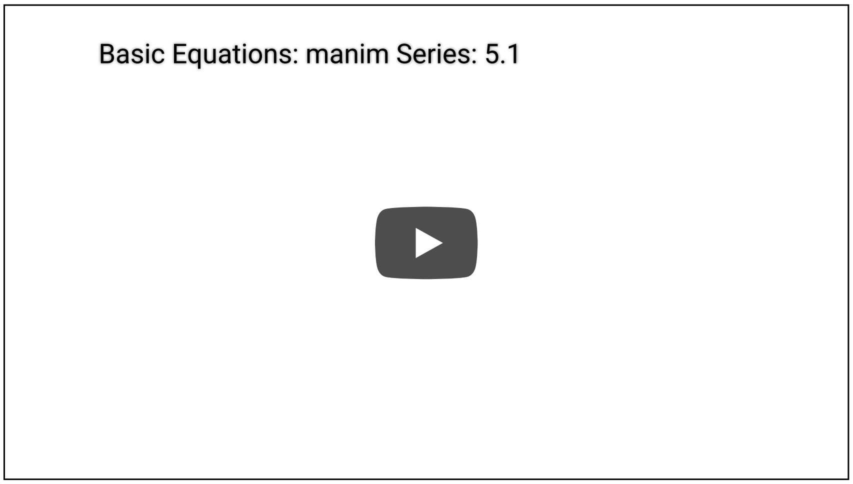
Things to play with
– Try changing the fill opacity for both the square and the background rectangle
– Try rotating the background rectangle separately from the the text
– Change the color of label2 to see how it affects the readability of the text
– Change the colors of "Rainbow"
– Place the "Rainbow" text on a different edge of the screen.

5.0 Mathematical Equations

A math animation package wouldn't be much use if you couldn't include nice looking equations. The best way I know of to typeset equations is using LaTeX ($\LaTeX$) , which manim makes use of. If you'd like to learn more about typesetting with LaTeX I'd recommend the tutorials at [ShareLaTeX]() for a basic intro, but you don't need to know much about LaTeX to use manim. You can find a list of commonly used symbols [here](), which is about all you need to know for manim.

Use manim to run the following scene from the tutorial file to see the following scene:

```
class BasicEquations(Scene):
    #A short script showing how to use Latex commands
    def construct(self):
        eq1=TextMobject("$\\vec{X}_0 \\cdot \\vec{Y}_1 = 3$")
        eq1.shift(2*UP)
        eq2=TexMobject(r"\vec{F}_{net} = \sum_i \vec{F}_i")
        eq2.shift(2*DOWN)

        self.play(Write(eq1))
        self.play(Write(eq2))
```



In LaTeX you normally enclose an equation with dollar signs $$ to denote an equation and that works here as well. The main difference is that, due to how manim parses the text, an extra backslash must be included in front of all LaTeX commands. For instance Greek letters can be created in LaTeX by typing out the name of the letter preceded by a backslash; lower case alpha α would be \$\alpha\$, the angle theta θ would be \$\theta\$. In manim, however, a double backslash is needed so α would be \$\\alpha\$ and θ would be written as \$\\theta\$.

David Bieber [pointed out in a comment](#) that you can use the raw string literal flag in front of the quote symbol, which removes the need for the double-slashes before Latex symbols. Instead of typing out `eq2=TexMobject("\\vec{F}_{net} = \\sum_i \\vec{F}_i")` you can put the letter `r` in front of the opening quotes and remove the double-slashes so `eq2=TexMobject(r"\vec{F}_{net} = \sum_i \vec{F}_i")`. This makes the code more readable and makes it much easier for those of us who normally type Latex. Going forward I will use the raw tag `r` rather than double-slashes.

You can place a vector arrow over a variable such as $\vec{A}$ using `\vec{A}` (remember you either need to use double-slashes or use the raw string literal tag `r`). Whatever you place inside the brackets will show up on screen with an arrow over it. Subscripts are denoted by the underscore so $\vec{X}_0$ would be written as \$\vec{X}_0\$. If the subscript consists of more than a single character you can enclose the subscript in brackets. Thus $\vec{F}_{net}$ in manim would be \$\vec{F}_{net}\$.

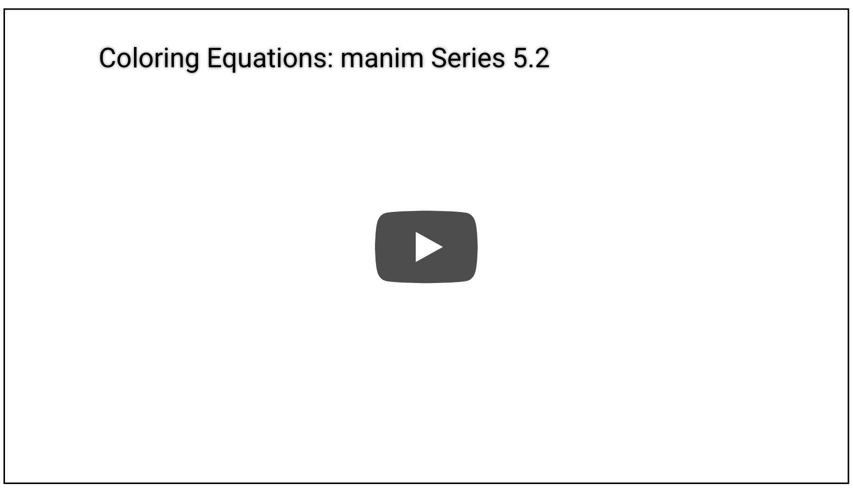
It can get tedious having to always include the dollar signs so the `TexMobject` class (which is different than a `TextMobject` – notice the missing 't' in the middle of the class name) assumes all strings are Latex strings. TEX ($\TeX$) is the typesetting language that LaTeX is based on so I assume `TexMobject` is named for TEX. The main difference between `TextMobject()` and `TexMobject` is the text math object assumes everything is plain text unless you specify an equation with dollar signs while the Tex math object assumes everything is an equation unless you specify something is plain text using `\\text{}`.

When mobjects of any sort are created the default position seems to be the center of the screen. Once created you can use `shift()` or `move_to()` to change the location of the mobjects. For this example above I've moved the equations either two MUnits up or two MUnits down (remember that the MUnit or **m**ath **unit** is what I call the measure of length inside manim). Since the screen height is set to a default of 8 MUnits, a 2 MUnit shift corresponds to about a quarter of the screen height.

The `Write()` method, which is a sublcass of `ShowCreation()`, takes a TextMobject or TexMobject and animates writing the text on the screen. You can also pass a string to `Write()` and it will create the TextMobject for you. `Write()` needs to be inside of `play()` in order to animate it.

5.1 Coloring Equations

```
class ColoringEquations(Scene):
    #Grouping and coloring parts of equations
    def construct(self):
        line1=TexMobject(r"\text{The vector } \vec{F}_{net} \text{ is the net }",r"\text{force }",r"\t
        line1.set_color_by_tex("force", BLUE)
        line2=TexMobject("m", "\\text{ and acceleration }", "\\vec{a}", ".  ")
        line2.set_color_by_tex_to_color_map({
            "m": YELLOW,
            "{a}": RED
        })
        sentence=VGroup(line1,line2)
        sentence.arrange_submobjects(DOWN, buff=MED_LARGE_BUFF)
        self.play(Write(sentence))
```



For this example we have broken our text into blocks of plain text and equations. This allows us to color parts of the text or equations using either `set_color_by_tex()` or `set_color_by_tex_to_color_map()`. For example, the reason the first sentence is broken up into three parts is so the word `force` can be colored blue. As far as I can tell there isn't an easy way in manim to make changes to part of a string. While you could use slicing of a string, I'm following the convention that Grant Sanderson uses and breaking up text into a list of strings.

The `set_color_by_tex()` method takes the individual string you want colors and the color as arguments. It looks like you only have to specify part of a string to match but the entire string gets colored. For instance, if we type in `line1.set_color_by_tex("F",BLUE)`, the only place a capital F occurs is in the force variable so the first part of this line is blue. If instead we try `line1.set_color_by_tex("e",BLUE)`, the letter `e` appears in several places in `line1` so the entire line ends up blue. If you want to change the color of multiple elements within a list of texmobjects you can use `set_color_by_tex_to_color_map()` and a dictionary. The key for the dictionary should be the text we want colored (or a unique part of the string) and the value should be the desired color.

Notice that, since we are using a texmobject and not a textmobject, we have to enclose plain text in the LaTeX command `\\text{}`. If you don't do this the text is assumed to be part of an equation so the font and spacing are of the text looks funny. Thus "the net force on object of mass" would look like $the net force on object of mass$. The equation environment doesn't recognize spaces between words, uses a different font, and spaces the letters differently than normal text.

By grouping the two lines together with `VGroup()`, we can use the `arrange_submobjects()` method to space out the two lines. The first argument is the direction you want the objects spaced out and `buff` is the buffer distance between the mobjects. There are several default buffer distances defined in `constants.py` but you can also a single number. The smallest default buffer is `SMALL_BUFF=0.1` and the largest is `LARGE_BUFF=1`. Although I didn't dive into the code, I think the way the buffers work is as a multiplicative factor of one of the main directional vectors (e.g. `UP`, `DOWN`, `LEFT`, `RIGHT`) so that specifying `SMALL_BUFF` and `LEFT` would be equivalent to $0.1 * (-1, 0, 0) = (-0.1, 0, 0)$.

Things to try:
– Create your own equations using the symbols here.
– Try changing the colors of different parts of the equations
– Use `set_color_by_tex` and match only a part of a full string to see how the entire string is changed
– Write out a sentence as a single string and then use slicing to create texmobjects

6.0 Aligning Text and Using Braces

Let's look at how to use braces to visually group equations or text together but also how to align text elements. We will first write a program to align elements of two equations but in a somewhat clunky fashion; this is not the most elegant way to accomplish this task. After looking at this first version we will rewrite the code in a more concise fashion that lines everything up even better.

You can find the following code in the manim tutorial file.

```
class UsingBraces(Scene):
    #Using braces to group text together
    def construct(self):
        eq1A = TextMobject("4x + 3y")
        eq1B = TextMobject("=")
        eq1C = TextMobject("0")
        eq2A = TextMobject("5x -2y")
        eq2B = TextMobject("=")
        eq2C = TextMobject("3")
        eq1B.next_to(eq1A,RIGHT)
        eq1C.next_to(eq1B,RIGHT)
        eq2A.shift(DOWN)
        eq2B.shift(DOWN)
        eq2C.shift(DOWN)
        eq2A.align_to(eq1A,LEFT)
        eq2B.align_to(eq1B,LEFT)
        eq2C.align_to(eq1C,LEFT)

        eq_group=VGroup(eq1A,eq2A)
        braces=Brace(eq_group,LEFT)
        eq_text = braces.get_text("A pair of equations")
```

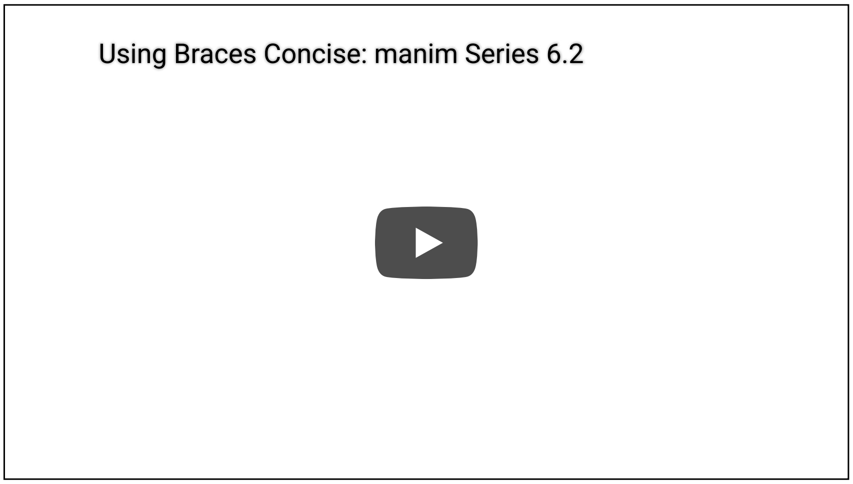
```
        self.add(eq1A, eq1B, eq1C)
        self.add(eq2A, eq2B, eq2C)
        self.play(GrowFromCenter(braces),Write(eq_text))
```

To line up parts of the equations on screen we use `next_to()` and `align_to()`. For this example we've broken the equation into smaller parts and then used `next_to()` to place the subparts of each equation next to each other and then `align_to()` to line up the left side of each part of the equation. You can also use `UP`, `DOWN`, and `RIGHT` to align different edges of the mobjects.

We've also added a brace to show how to visually group a set of equations. In order to use the braces we must use `VGroup()` to combine the equations. When we instantiate the braces the first argument is the group and the second argument is where the braces are located relative to the grouping. You can set the text next to the braces using `get_text()` (this is a little confusing naming because you are setting the text, not getting it). This method does not draw the text on the screen, it is only used to set the location of the text relative to the braces so you will still need to add the text to the screen.

```
class UsingBracesConcise(Scene):
    #A more concise block of code with all columns aligned
    def construct(self):
        eq1_text=["4","x","+","3","y","=","0"]
        eq2_text=["5","x","-","2","y","=","3"]
        eq1_mob=TexMobject(*eq1_text)
        eq2_mob=TexMobject(*eq2_text)
        eq1_mob.set_color_by_tex_to_color_map({
            "x":RED_B,
            "y":GREEN_C
            })
        eq2_mob.set_color_by_tex_to_color_map({
            "x":RED_B,
            "y":GREEN_C
            })
        for i,item in enumerate(eq2_mob):
            item.align_to(eq1_mob[i],LEFT)
        eq1=VGroup(*eq1_mob)
        eq2=VGroup(*eq2_mob)
        eq2.shift(DOWN)
        eq_group=VGroup(eq1,eq2)
        braces=Brace(eq_group,LEFT)
```

```
        eq_text = braces.get_text("A pair of equations")

        self.play(Write(eq1),Write(eq2))
        self.play(GrowFromCenter(braces),Write(eq_text))
```



Here is a (somewhat) more concise version of the previous code. Each equation is written out as a list with each part of the equation as a separate string. This allows more control over the vertical alignment of the parts of the two equations. Inside the `for` loop we use `align_to()` to line up the left edge of the elements in `eq1` and `eq2`.

Notice that when creating the texmobjects that we passed the variable name of the list with an asterisk in front of it `eq1_mob=TexMobject(*eq1_text)`. The asterisk is a Python command to unpack the list and treat the argument as a comma-separated list. Thus `eq1_mob=TexMobject(*eq1_text)` is identical to `eq1_mob=TexMobject("4","x","+","3","y","=","0")`.

Things to try:
– Arrange the equations on the screen
– Add some shapes around your equations.

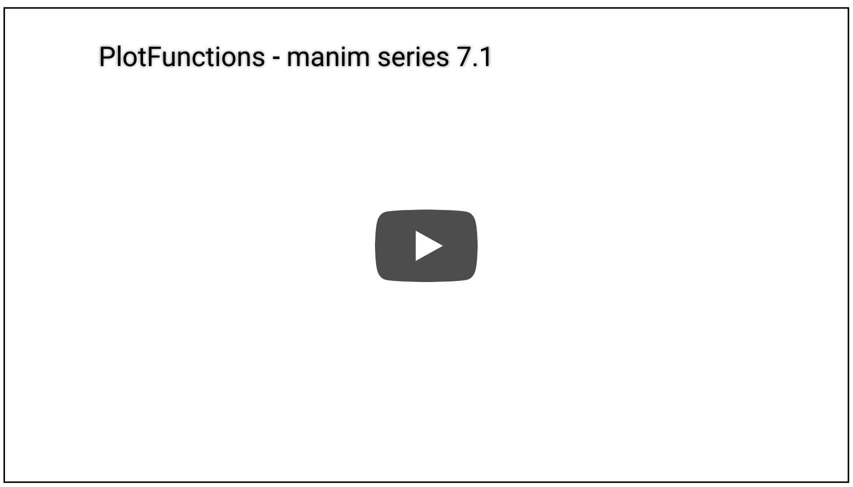
7.0 Graphing Functions

The easiest way to plot functions is to base your scene class on the `GraphScene()`. The scene creates a set of axes and has methods for creating graphs. One thing that confused me a little at first is that the axes belong to your scene class so you will need to use `self` to access the methods related to the axes. This caused me a few issues when I started out.

We will start off by looking at how to create the axes and graphs but we will come back to look at the `CONFIG{}` dictionary, which is used frequently in manim for initializing many of the class variables.

```
class PlotFunctions(GraphScene):
    CONFIG = {
        "x_min" : -10,
        "x_max" : 10.3,
        "y_min" : -1.5,
        "y_max" : 1.5,
        "graph_origin" : ORIGIN ,
        "function_color" : RED ,
```

```
            "axes_color" : GREEN,
            "x_labeled_nums" :range(-10,12,2),
        }
    def construct(self):
        self.setup_axes(animate=True)
        func_graph=self.get_graph(self.func_to_graph,self.function_color)
        func_graph2=self.get_graph(self.func_to_graph2)
        vert_line = self.get_vertical_line_to_graph(TAU,func_graph,color=YELLOW)
        graph_lab = self.get_graph_label(func_graph, label = "\\cos(x)")
        graph_lab2=self.get_graph_label(func_graph2,label = "\\sin(x)", x_val=-10, direction=UP/2)
        two_pi = TexMobject("x = 2 \\pi")
        label_coord = self.input_to_graph_point(TAU,func_graph)
        two_pi.next_to(label_coord,RIGHT+UP)

        self.play(ShowCreation(func_graph),ShowCreation(func_graph2))
        self.play(ShowCreation(vert_line), ShowCreation(graph_lab), ShowCreation(graph_lab2),ShowCreat

    def func_to_graph(self,x):
        return np.cos(x)

    def func_to_graph2(self,x):
        return np.sin(x)
```



Under the `construct` method, the first line is `self.setup_axes()` which will create a set of axes on screen. With the exception of whether the creation is animated or not, all other variables for the axes are set using `CONFIG{}`, which I'll explain in a bit. The default values for the `GraphScene()` (which are located in graph_scene.py) are shown below:

```
CONFIG = {
    "x_min": -1,
    "x_max": 10,
    "x_axis_width": 9,
    "x_tick_frequency": 1,
    "x_leftmost_tick": None, # Change if different from x_min
    "x_labeled_nums": None,
    "x_axis_label": "$x$",
    "y_min": -1,
    "y_max": 10,
    "y_axis_height": 6,
    "y_tick_frequency": 1,
    "y_bottom_tick": None, # Change if different from y_min
    "y_labeled_nums": None,
```

```
        "y_axis_label": "$y$",
        "axes_color": GREY,
        "graph_origin": 2.5 * DOWN + 4 * LEFT,
        "exclude_zero_label": True,
        "num_graph_anchor_points": 25,
        "default_graph_colors": [BLUE, GREEN, YELLOW],
        "default_derivative_color": GREEN,
        "default_input_color": YELLOW,
        "default_riemann_start_color": BLUE,
        "default_riemann_end_color": GREEN,
        "area_opacity": 0.8,
        "num_rects": 50,
    }
```

With our example we have changed `x_min`, `x_max`, `y_min`, `y_max`, `graph_origin`, `axes_color`, and `x_labeled_num`. The values assigned in our class take priority over values set by the parent class. Every value that we don't change is automatically assigned the value defined in the parent class. The `x_labeled_num` property takes a list of numbers for labels along the x-axis. We've used `range(-10,12,2)` to generate a list of values from -10 to +10 in steps of 2. One issue I've noted with the y-axis is that setting the min values along either axis to numbers that are not integer multiples of 0.5 results in the tick marks along that axis not being symmetric about zero (e.g. try `y_min` = -1.2). I'm not sure what that is about but it isn't a problem if you stick to integer multiples of 0.5 you don't have any problems.

Once you have the axes set up you can use `self.get_graph()` to graph a function. The argument of `get_graph()` needs to be a pointer to a function, rather than a call to the function itself. In other words, since one of my functions is `func_to_graph()` I should use `self.get_graph(func_to_graph)` without any parentheses after `func_to_graph`.

Rather than defining separate functions for graphing we could use lambda functions. For example, if I define `self.func = lambda x: np.cos(x)` and then use `self.get_graph(self.func)` I will get the same result.

With `get_graph()` you do need to explicitly pass arguments rather than using `CONFIG{}`. The possible arguments, in addition to the function to graph, are `color`, `x_min`, and `x_max`. If you don't specify a color `GraphScene` will cylce through `BLUE`, `GREEN`, and `YELLOW` for successive graphs. Since I didn't specify a color for my second graph it was automatically assigned the first color, `BLUE`.

There is a handy method to draw a vertical line from the x-axis to the graph called `get_vertical_line_to_graph()`. I love that the method naming convention is descriptive enough that you can see what each method does at a glance. Good job, Grant! The arguments for `get_vertical_line_to_graph()` are the x-value where you want the line and the particular graph you want the line drawn to. Note that `get_vertical_line_to_graph()` is a method of the `GraphScene` and not the graph or axes so it is called with `self.get_vertical_line_to_graph()`.

You can label graphs using `get_graph_label()` to set the text associated with the graph. This is similar to the `get_text()` method of the `Braces()` class in that it creates a texmobject at a specific location but does not draw it on the screen; you need to `add` or `play` to show the label. The arguments for `get_graph_label()` are the particular graph you want to add a label to and the text for the label. If you don't specify an x-value and/or direction the label is placed at the end of the graph. The `direction` specifies where, relative to the `x_value` you want the label placed.

There are several other methods associated with the `GraphScene()` that are worth looking at, but I found the `input_to_graph_point()` to be very helpful. By specifying an x-value on the graph, this method will return the coordinate on the screen where that graph point lies. This is handy if you want to place some text or other mobject to call out a particular point on a graph.

7.1 The CONFIG{} Dictionary

Whenever a scene or mobject are created a method called `digest_config()` gets called. This method starts with the class you defined and looks for a dictionary called `self.CONFIG` and compiles a list of all entries in the dictionary. It then goes to the parent class and looks for `self.CONFIG` there and adds those entries. If the method comes across keys that have already been found, it ignores the values from the parent class. `digest_config()` keeps traveling up the hierarchy to the top parent class, with is `Container()`. Each entry in this dictionary is then assigned a class variable based on the key and value. Thus the dictionary entry `"x_min" : -1` becomes `self.x_min = -1` and so on. Each dictionary entry becomes a class variable that can be accessed by the methods within the class. Understanding all of the `CONFIG{}` entries for a class is crucial to getting the most out of manim. For example, `GraphScene()` has the following `CONFIG{}` entries:

```
class GraphScene(Scene):
    CONFIG = {
        "x_min": -1,
        "x_max": 10,
        "x_axis_width": 9,
        "x_tick_frequency": 1,
        "x_leftmost_tick": None, # Change if different from x_min
        "x_labeled_nums": None,
        "x_axis_label": "$x$",
        "y_min": -1,
        "y_max": 10,
        "y_axis_height": 6,
        "y_tick_frequency": 1,
        "y_bottom_tick": None, # Change if different from y_min
        "y_labeled_nums": None,
        "y_axis_label": "$y$",
        "axes_color": GREY,
        "graph_origin": 2.5 * DOWN + 4 * LEFT,
        "exclude_zero_label": True,
        "num_graph_anchor_points": 25,
        "default_graph_colors": [BLUE, GREEN, YELLOW],
        "default_derivative_color": GREEN,
        "default_input_color": YELLOW,
        "default_riemann_start_color": BLUE,
        "default_riemann_end_color": GREEN,
        "area_opacity": 0.8,
        "num_rects": 50,
    }
```

The parent class for `GraphScene()` (found in the scene.py file) has the following dictionary:

```
class Scene(Container):
    CONFIG = {
```

```
        "camera_class": Camera,
        "camera_config": {},
        "frame_duration": LOW_QUALITY_FRAME_DURATION,
        "construct_args": [],
        "skip_animations": False,
        "ignore_waits": False,
        "write_to_movie": False,
        "save_frames": False,
        "save_pngs": False,
        "pngs_mode": "RGBA",
        "movie_file_extension": ".mp4",
        "name": None,
        "always_continually_update": False,
        "random_seed": 0,
        "start_at_animation_number": None,
        "end_at_animation_number": None,
        "livestreaming": False,
        "to_twitch": False,
        "twitch_key": None,
    }
```

`Container()`, the parent to `Scene` as well as `Mobject`, has no `CONFIG{}` entries.

When talking about mobjects, the list of `CONFIG{}` entries can get a little long. I won't go into those right now but it is worth you time to take a look at the hierarchy of some of the mobject subclasses to see what all the properties you can control are.

8.0 More Graphing

Let's take a deeper dive into some of the graphing features in manim.

```
class ExampleApproximation(GraphScene):
    CONFIG = {
        "function" : lambda x : np.cos(x),
        "function_color" : BLUE,
        "taylor" : [lambda x: 1, lambda x: 1-x**2/2, lambda x: 1-x**2/math.factorial(2)+x**4/math.fact
        lambda x: 1-x**2/math.factorial(2)+x**4/math.factorial(4)-x**6/math.factorial(6)+x**8/math.fac
        "center_point" : 0,
        "approximation_color" : GREEN,
        "x_min" : -10,
        "x_max" : 10,
        "y_min" : -1,
        "y_max" : 1,
        "graph_origin" : ORIGIN ,
        "x_labeled_nums" :range(-10,12,2),

    }
    def construct(self):
        self.setup_axes(animate=True)
        func_graph = self.get_graph(
            self.function,
            self.function_color,
        )
        approx_graphs = [
            self.get_graph(
```

```
                f,
                self.approximation_color
            )
            for f in self.taylor
        ]

        term_num = [
            TexMobject("n = " + str(n),aligned_edge=TOP)
            for n in range(0,8)]
        #[t.to_edge(BOTTOM,buff=SMALL_BUFF) for t in term_num]


        #term = TexMobject("")
        #term.to_edge(BOTTOM,buff=SMALL_BUFF)
        term = VectorizedPoint(3*DOWN)

        approx_graph = VectorizedPoint(
            self.input_to_graph_point(self.center_point, func_graph)
        )

        self.play(
            ShowCreation(func_graph),
        )
        for n,graph in enumerate(approx_graphs):
            self.play(
                Transform(approx_graph, graph, run_time = 2),
                Transform(term,term_num[n])
            )
            self.wait()
```

I wanted to demonstrate how adding higher terms in a Taylor expansion results in better and better agreement with a function. This is similar to what shinigamiphoenix posted [here](#).

The functions to plot are defined as lambda functions in the `CONFIG{}` dictionary. As previously mentioned, manim processes all elements in `CONFIG{}` and turns the dictionary entries into class variables with the key as the variable name. Thus `"function"` can be accessed within my class by calling `self.function` and `"taylor"` can be called with `self.taylor`. If you aren't familiar with lambda functions, check out [this](#) post at [Python Conquers the Universe](#).

We create a list of graphs using `get_graph()` and a list comprehension. You can find a nice tutorial on list comprehensions over at datacamp.com. It was only after reading this tutorial that I made the connection between list comprehensions and mathematical notation for definitions of sets (e.g. the set of positive real numbers is {$x|x \in$ R and $x > 0$} or the set of even numbers which is {$x|x \in$ I and $x\ mod(2) = 0$}), which made list comprehensions click for me. For each item in the list `self.taylor`, a graph is created with color `self.approximation_color`. We also created a list of TexMobjects to indicate which order of terms are included from the Taylor expansion using a list comprehension.

Since we are going to do successive transformations from a list, it helps to have a blank placeholder on the screen. `term` and `approx_graph` are `VectorizedPoint` instances, which are mobjects that don't display anything on screen. This way we can put the placeholders on the screen without anything appearing, and then transform those mobjects into either the graph or the TexMobjects.

The `enumerate()` command is a useful tool that iterates over a list and also returns the index of the item returned. Thus `for n,graph in enumerate(approx_graphs)` returns the index between 0 and 4 as `n`, and the element within the list as `graph`. This is used to display the corresponding item from `term_num` with each graph.

9.0 Vector Fields

Before diving into draw a vector field, we should set up a Cartesian axes using `NumberPlane()`. This gives you two axes and an underlying grid. The `CONFIG{}` for the `NumberPlane()` (found in the coordinate_systems.py file) is:

```
class NumberPlane(VMobject):
    CONFIG = {
        "color": BLUE_D,
        "secondary_color": BLUE_E,
        "axes_color": WHITE,
        "secondary_stroke_width": 1,
        # TODO: Allow coordinate center of NumberPlane to not be at (0, 0)
        "x_radius": None,
        "y_radius": None,
        "x_unit_size": 1,
        "y_unit_size": 1,
        "center_point": ORIGIN,
        "x_line_frequency": 1,
        "y_line_frequency": 1,
        "secondary_line_ratio": 1,
        "written_coordinate_height": 0.2,
        "propagate_style_to_family": False,
        "make_smooth_after_applying_functions": True,
    }
```

You can change any of these default values by passing a dictionary with new values as keyword arguments. For example, if you want to change the spacing of the grid lines you could change `x_line_frequency` and `y_line_frequency` by defining a dictionary with these variables and then passing the dictionary to `NumberPlane()`. If you want to see the x-axis and y-axis indicated you can use `get_axis_labels()` to draw an `x` and a `y` next to the appropriate axis. See the code below.

```
class DrawAnAxis(Scene):
    CONFIG = { "plane_kwargs" : {
        "x_line_frequency" : 2,
        "y_line_frequency" :2
        }
    }

    def construct(self):
        my_plane = NumberPlane(**self.plane_kwargs)
        my_plane.add(my_plane.get_axis_labels())
        self.add(my_plane)
```

The double asterisk in front of the argument `self.plane_kwargs` lets the class know that this is a dictionary that needs to be unpacked.

I recommend changing the various properties to see what affect they have on the axes and grid. This is the best way to learn what things do.

9.1 A Simple Vector Field

Let’s start with a simple vector field; a constant field. We first need to define a set of vector points for each grid point, define the field at each grid point, then create the `Vector()` for the field at each point. Finally we combine all the `Vector()` instances into a `VGroup` to allow us to draw all vector lines with a single command.

```
class SimpleField(Scene):
    CONFIG = {
    "plane_kwargs" : {
        "color" : RED
        },
    }
    def construct(self):
        plane = NumberPlane(**self.plane_kwargs)
        plane.add(plane.get_axis_labels())
        self.add(plane)

        points = [x*RIGHT+y*UP
            for x in np.arange(-5,5,1)
            for y in np.arange(-5,5,1)
```

```
        ]

    vec_field = []
    for point in points:
        field = 0.5*RIGHT + 0.5*UP
        result = Vector(field).shift(point)
        vec_field.append(result)

    draw_field = VGroup(*vec_field)


    self.play(ShowCreation(draw_field))
```

After creating the `NumberPlane()` we use a list comprehension to create a list of the location of all grid points. Remember that `RIGHT=np.array(1,0,0)` and `UP=np.array(0,1,0)` so this list comprehension covers all points from (5,5,0) down to (-5,-5,0) in unit step sizes. The last number in `arange()` specifies the step size. Next we create an empty list `vec_field` to hold all of the vectors we are going to create. The `for` loop goes through each grid location in `points` and creates a vector whose length and direction are defined by `field`. It is inefficient to keep defining `field` each time through the loop but we are setting things up for later. The `shift(point)` command moves the vector to the grid location defined by `point`. These results are then appended to a list. After going through the `for` loop, all of the vectors are grouped together in a single `VGroup` called `draw_field`. The only reason for doing this is that you can then add `draw_field` using a single `add` or `play` command. You could have included `self.add(result)` inside each iteration of the `for` loop instead of showing the creation of `draw_field`, but using the `VGroup` feels cleaner.

9.2 A Variable Vector Field

For a slightly more interesting field we will look at the electric field due to a postive point charge. The electric field is:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^3}\vec{r}$$

where q_1 is the charge on the point charge, $\vec{r}$ is the distance vector between the charge and the observation point, and r is the magnitude of that vector. The constant out front $\frac{1}{4\pi\epsilon_0} = 9\times10^9 Nm^2/C^2$ is essentially a conversion factor. For our purposes we will set all constants equal to zero and just look at

$$\vec{E} = \frac{1}{r^3}\vec{r}.$$

```
class FieldWithAxes(Scene):
    CONFIG = {
    "plane_kwargs" : {
        "color" : RED_B
        },
    "point_charge_loc" : 0.5*RIGHT-1.5*UP,
    }
    def construct(self):
        plane = NumberPlane(**self.plane_kwargs)
        plane.add(plane.get_axis_labels())
        self.add(plane)

        field = VGroup(*[self.calc_field(x*RIGHT+y*UP)
            for x in np.arange(-9,9,1)
            for y in np.arange(-5,5,1)
            ])

        self.play(ShowCreation(field))


    def calc_field(self,point):
        #This calculates the field at a single point.
        x,y = point[:2]
        Rx,Ry = self.point_charge_loc[:2]
        r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
        efield = (point - self.point_charge_loc)/r**3
        #efield = np.array((-y,x,0))/math.sqrt(x**2+y**2)  #Try one of these two fields
        #efield = np.array(( -2*(y%2)+1 , -2*(x%2)+1 , 0 ))/3  #Try one of these two fields
        return Vector(efield).shift(point)
```

The location of the point charge is set in `CONFIG{}`. To create the vector field we've condensed the previous code. We use a list comprehension and the function `calc_field()` as the argument of `VGroup()`. The `calc_field()` function defines the field to calculate. To make the formulas a little easier to read we unpack the x- and y-coordinates from the `point` vector and the `self.point_charge_loc` vector. The code `x,y=point[:2]` is equivalent to `x=point[0]` and `y=point[1]`.

The `fade(0.9)` method sets the opacity of the lines to be one minus the fade level (so in this case the opacity is set to 0.1). This was done to make it easier to see the tiny field arrows farther from the charge location.

Things to try:

– Change each of the elements in `CONFIG{}` for `NumberPlane()` to see what affect they have on the axes and grid lines.

– Calculate different fields

– Try `efield = np.array((-y,x,0))/math.sqrt(x**2+y**2)`

– Try `efield = np.array(( -2*(y%2)+1 , -2*(x%2)+1 , 0 ))/3`

– Come up with your own equation

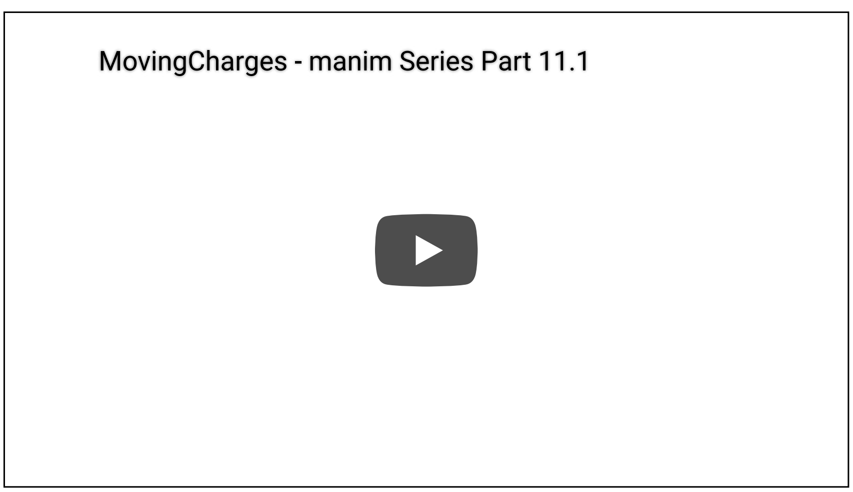
10.0 Field of a Moving Charge

There was a [question over on Reddit]() about how to create the electric field of a moving charge. Since that is something I will want to do at some point I figured it would be fun to give it a try.

Before creating a changing field, I thought I'd start with moving charges around. I know I saw this in one of the videos so I can start with working code and modify it to my needs. Here is what I came up with:

```
class MovingCharges(Scene):
    CONFIG = {
    "plane_kwargs" : {
        "color" : RED_B
        },
    "point_charge_loc" : 0.5*RIGHT-1.5*UP,
    }
    def construct(self):
        plane = NumberPlane(**self.plane_kwargs)
        plane.add(plane.get_axis_labels())
        self.add(plane)

        field = VGroup(*[self.calc_field(x*RIGHT+y*UP)
            for x in np.arange(-9,9,1)
            for y in np.arange(-5,5,1)
            ])
        self.field=field
        source_charge = self.Positron().move_to(self.point_charge_loc)
        self.play(FadeIn(source_charge))
        self.play(ShowCreation(field))
        self.moving_charge()

    def calc_field(self,point):
        x,y = point[:2]
        Rx,Ry = self.point_charge_loc[:2]
        r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
        efield = (point - self.point_charge_loc)/r**3
        return Vector(efield).shift(point)

    def moving_charge(self):
        numb_charges=4
        possible_points = [v.get_start() for v in self.field]
        points = random.sample(possible_points, numb_charges)
        particles = VGroup(*[
            self.Positron().move_to(point)
            for point in points
        ])
        for particle in particles:
            particle.velocity = np.array((0,0,0))
```

```
        self.play(FadeIn(particles))
        self.moving_particles = particles
        self.add_foreground_mobjects(self.moving_particles )
        self.always_continually_update = True
        self.wait(10)

    def field_at_point(self,point):
        x,y = point[:2]
        Rx,Ry = self.point_charge_loc[:2]
        r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
        efield = (point - self.point_charge_loc)/r**3
        return efield

    def continual_update(self, *args, **kwargs):
        if hasattr(self, "moving_particles"):
            dt = self.frame_duration
            for p in self.moving_particles:
                accel = self.field_at_point(p.get_center())
                p.velocity = p.velocity + accel*dt
                p.shift(p.velocity*dt)


    class Positron(Circle):
        CONFIG = {
        "radius" : 0.2,
        "stroke_width" : 3,
        "color" : RED,
        "fill_color" : RED,
        "fill_opacity" : 0.5,
        }
        def __init__(self, **kwargs):
            Circle.__init__(self, **kwargs)
            plus = TexMobject("+")
            plus.scale(0.7)
            plus.move_to(self)
            self.add(plus)
```



The most important method here is `continual_update()`. This method updates the screen for each frame during the entire scene. This differs from the various transformations that rely on the `play()` method in that the transformations occur over a short time interval, usually on the order of a few seconds while the continual methods continue to run for the entire scene. If we want a particle to move across the screen we might be tempted to use something like `self.play(ApplyMethod(particle1.shift,5*LEFT))` but it would be challenging to control the timing of other transformations going on at the same time. The `continual_update()` allows you to animate things in the background while still controlling the timing of other transformations.

Since I know I will be using charged particles in my videos I've written a `Positron` class to create positively charged particles. The positron is the positive antiparticle of the electron. Why didn't I make it a proton? Because the proton is roughly 2000 times more massive and I want similarly sized particles for what I want to do.

We've reused the code from a [previous post] about electric fields but we've added methods to create the charged particles and move them around. `moving_charge()` is what creates positrons by randomly selecting a field point (`possible_points = [v.get_start() for v in self.field]` is a list of the locations of the tails of all field vectors) and then selects `numb_charges` points to create particles at. Note that the randomly generated charges don't react to one another, which I find disturbing to watch because it isn't physical.

`particles` is a vectorized mobject group that contains all of the moving charges with initial velocities set to zero (`particle.velocity = np.array((0,0,0))`). We could have simplified the code by only using one particle at a set location, but we'll need multiple charges later on. The charges are then added to the screen (`self.play(FadeIn(particles))`) and assigned to a class variable that is needed in `continual_update` (`self.moving_particles = particles`). Mobjects are drawn in the order they are added to the screen but you can place certain mobjects in the foreground to insure they always remain drawn on top of other objects by using `add_foreground_mobjects()`. It is kind of like layers in Photoshop or similar software except each mobject is in its own layer. This has to do with the fact that manim keeps all mobjects drawn on the screen in a list and draws them in the order they are listed. There is no equivalent background mobject method, but you can send mobjects to the front or back layers with `bring_to_front()` and `bring_to_back()`.

Next we tell manim to continually update things in the background (`self.always_continually_update = True`) and then wait ten seconds. It is important to set the `wait()` command because the continual update only runs as long as their are animation elements (`play()` commands) or `wait()` commands in the animation queue.

The `field_at_point()` method duplicates some of the earlier code but is used to return a numerical vector (a numpy 3-element array) rather than a mobject `Vector`, which is what `calc_field()` returns. It took me an embarassing amount of time to figure out why I couldn't just use `calc_field()` to find the force vector.

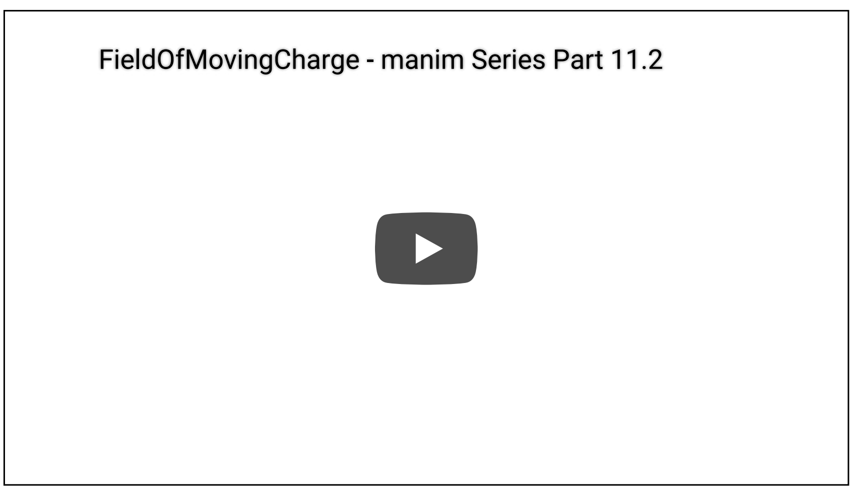
The `continual_update()` method is called each frame when the scene is being composed. The first line, `if hasattr(self, "moving_particles"):` prevents the rest of the code running and throwing and error if you haven't created `self.moving_particles`. The frame duration is either 1/15, 1/30, or 1/60 of a second, depending on whether your video is low, medium, or production quality (i.e. whether you include -l, -m, or no command line argument when extracting the scene). We run through the list of all moving particles (`for p in self.moving_particles:`) and then calculate the acceleration due to the electric field at the location of each particle (`vect = self.field_at_point(p.get_center())`). `p.get_center()` returns the vector location of each particle `p`. The velocity is updated using $\vec{v}_f = \vec{v}_i + a\Delta t$ and then the particle is shifted over the distance $\vec{v}_f \Delta t$.

10.1 Updating the Electric Field of a Moving Charge

Now we've got some experience moving things around on the screen so we can move on to calculating the field due to the particle. We will reuse much of the code from our previous program, with a few changes.

```
class FieldOfMovingCharge(Scene):
    CONFIG = {
    "plane_kwargs" : {
        "color" : RED_B
        },
    "point_charge_start_loc" : 5.5*LEFT-1.5*UP,
    }
    def construct(self):
        plane = NumberPlane(**self.plane_kwargs)
        #plane.main_lines.fade(.9)
        plane.add(plane.get_axis_labels())
        self.add(plane)

        field = VGroup(*[self.create_vect_field(self.point_charge_start_loc,x*RIGHT+y*UP)
            for x in np.arange(-9,9,1)
            for y in np.arange(-5,5,1)
            ])
        self.field=field
        self.source_charge = self.Positron().move_to(self.point_charge_start_loc)
        self.source_charge.velocity = np.array((1,0,0))
        self.play(FadeIn(self.source_charge))
        self.play(ShowCreation(field))
        self.moving_charge()

    def create_vect_field(self,source_charge,observation_point):
        return Vector(self.calc_field(source_charge,observation_point)).shift(observation_point)

    def calc_field(self,source_point,observation_point):
        x,y,z = observation_point
        Rx,Ry,Rz = source_point
        r = math.sqrt((x-Rx)**2 + (y-Ry)**2 + (z-Rz)**2)
        if r<0.0000001:   #Prevent divide by zero  ##Note:  This won't work - fix this
            efield = np.array((0,0,0))
        else:
            efield = (observation_point - source_point)/r**3
        return efield



    def moving_charge(self):
        numb_charges=3
        possible_points = [v.get_start() for v in self.field]
        points = random.sample(possible_points, numb_charges)
        particles = VGroup(self.source_charge, *[
            self.Positron().move_to(point)
            for point in points
        ])
        for particle in particles[1:]:
            particle.velocity = np.array((0,0,0))
        self.play(FadeIn(particles[1:]))
        self.moving_particles = particles
        self.add_foreground_mobjects(self.moving_particles )
        self.always_continually_update = True
        self.wait(10)
```

```
def continual_update(self, *args, **kwargs):
    Scene.continual_update(self, *args, **kwargs)
    if hasattr(self, "moving_particles"):
        dt = self.frame_duration

        for v in self.field:
            field_vect=np.zeros(3)
            for p in self.moving_particles:
                field_vect = field_vect + self.calc_field(p.get_center(), v.get_start())
            v.put_start_and_end_on(v.get_start(), field_vect+v.get_start())

        for p in self.moving_particles:
            accel = np.zeros(3)
            p.velocity = p.velocity + accel*dt
            p.shift(p.velocity*dt)


class Positron(Circle):
    CONFIG = {
    "radius" : 0.2,
    "stroke_width" : 3,
    "color" : RED,
    "fill_color" : RED,
    "fill_opacity" : 0.5,
    }
    def __init__(self, **kwargs):
        Circle.__init__(self, **kwargs)
        plus = TexMobject("+")
        plus.scale(0.7)
        plus.move_to(self)
        self.add(plus)
```



One change we've made is to let `calc_field()` return a numpy vector rather than a mobject `Vector`. This does mean adding in `create_vect_field()` to create the mobjects from the numpy vectors.

Since we want our source charge to be able to move we have to add that source charge to the `particles` list. Thus the Vgroup we create includes that source charge plus the randomly generated charges using `particles = VGroup(self.source_charge, *[self.Positron().move_to(point) for point in points])`. Remember that the asterisk in front of the list lets Python know that each element in the list should be broken out and treated as a separate argument for the `VGroup()` class. To help make sense of this line of code we can break it out into a less elegant form:

```
list_of_random_charges=[]
for point in points:
    new_charge = self.Positron().move_toe(point)
    list_of_random_charges.append(new_charge)
    particles = VGroup(self.source_charge, list_of_random_charges[0],
    list_of_random_charges[1], list_of_random_charges[2])
```

Thus one line of code replaces several lines. The reason we use `particles[1:]` in the code defining the velocity and fading in the particles is that the source charge already has a velocity and is on screen so we don't want to redefine the velocity or have it fade in again (which makes it blink).

In `continual_update()` we now need to calculate the field at each grid point at each time step. First we cycle through each field point (`for v in self.field:`). Since we want to add up the fields from several charges, we set the field vector to zero (`field_vect=np.zeros(3)`) and then add up the fields at that point due to each charge (`field_vect = field_vect + self.calc_field(p.get_center(), v.get_start())`). We need to redraw the field vectors by specifying the start and end points of the vector. The start point is the initial grid point where the vector starts (`v.get_start()`) and the tip of the arrow is a distance equal to the field vector plus the starting point (`field_vect+v.get_start()`).

I don't have the particles react to the fields of the other particles. This looks very unrealistic to me but it should be easy enough to implement. I just wanted to put out a post that lays out the basics of how to get the field lines working.

11 Three Dimensional Scenes

This is the first place where this tutorial diverges from the previous series. This is due to the fact that many of the changes in manim after switching the Python 3.7 (at least that I've seen) seem to be focused on improving the 3D capabilities of manim.

This might be a good time to explain how I have been figuring manim out. The first thing I do is go to the active_projects directory, find a file related to an interesting video, and pick it apart. As long as you pick an active project you know it should compile without any problems. I will then copy and paste a single scene into another file and start stripping out components of the code until I have a simple working example of the thing I'm interested in. I'll start playing around with some of the CONFIG entries and start adding in features. I find it very useful to search the github site for other scenes that have used similar commands to determine what sort of options are available. The naming convention that Grant Sanderson uses is good enough that you can usually figure out what things do with only a little trial and error.

The CONFIG dictionary for the `ThreeDScene` class is:

```
class ThreeDScene(Scene):
    CONFIG = {
        "camera_class": ThreeDCamera,
        "ambient_camera_rotation": None,
        "default_angled_camera_orientation_kwargs": {
        "phi": 70 * DEGREES,
        "theta": -135 * DEGREES,
```

```
        }
    }
```

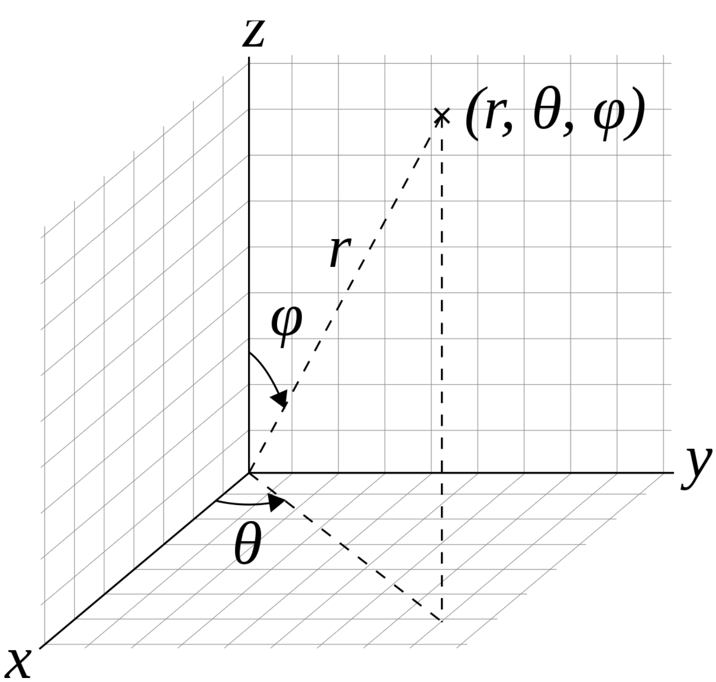
The methods you can call in a `ThreeDScene` (which can be found in [three_d_scene.py]) are:

- `set_camera_orientation`
- `begin_ambient_camera_rotation`
- `stop_ambient_camera_rotation`
- `move_camera`

There are a few other methods but we'll focus on these for now. To start with we will create a normal 2D scene but use the 3D camera to rotate around. We'll reuse the code from the previous section:

```
class ExampleThreeD(ThreeDScene):
    CONFIG = {
    "plane_kwargs" : {
        "color" : RED_B
        },
    "point_charge_loc" : 0.5*RIGHT-1.5*UP,
    }
    def construct(self):
        plane = NumberPlane(**self.plane_kwargs)
        plane.add(plane.get_axis_labels())
        self.add(plane)

        field2D = VGroup(*[self.calc_field2D(x*RIGHT+y*UP)
            for x in np.arange(-9,9,1)
            for y in np.arange(-5,5,1)
            ])

        self.set_camera_orientation(phi=PI/3,gamma=PI/5)
        self.play(ShowCreation(field2D))
        self.wait()
        #self.move_camera(gamma=0,run_time=1)  #currently broken in manim
        self.move_camera(phi=3/4*PI, theta=-PI/2)
        self.begin_ambient_camera_rotation(rate=0.1)
        self.wait(6)

    def calc_field2D(self,point):
        x,y = point[:2]
        Rx,Ry = self.point_charge_loc[:2]
        r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
        efield = (point - self.point_charge_loc)/r**3
        return Vector(efield).shift(point)
```

By defining our scene as a subclass of `ThreeDScene`, we gain access to the 3D camera options. Then it is just a matter of moving the camera around.



By Dmcq – Own work, CC BY-SA 3.0, Link

The original orientation of the camera is set using `set_camera_orientation()` which takes θ and ϕ. You can also set the distance from the camera to the origin using the keyword argument `distance`. There is also the option to change `gamma` (the greek letter γ), which is one of the Euler angles. Changing `gamma` causes the camera to rotate about an axis through the center of the lens, allowing us to change which direction is horizontal on the screen. Note that if we use `set_camera_orientation` in the middle of the scene the camera will jump to the new orientation.

One thing to keep in mind when setting the camera orientation is that, although the camera itself is pointing towards the origin, the angles θ, ϕ, and γ are measured from an axis set up at the center of the camera. For some reason $\phi = 0$ and $\theta = 0$ corresponds to the positive y-axis being ot the right and the positive x-axis being down. This is why $\phi = 0$ and $\theta = -\pi/2$ corresponds to the normal 2D orientation with the x-axis pointing right and the y-axis pointing up on the screen. If you set $\theta = \pi/2$ we flip the screen over.

To get the camera to smoothly pan we use `move_camera()`, which has the same arguments as `set_camera_orientation()`. ~~At the moment I'm not seeing a way how to change the rate at which the camera changes location – I'll put that on my to-do list for later.~~ Edit: It turns out you can specify `run_time=4` , for example, to have the `move_camera()` operation take 4 seconds.

We can set the camera rotating about the z-axis by calling `begin_ambient_camera_rotation()` and we can specify the rate at which it is rotating. I believe the `rate` is measured in radians per second.

If you are more familiar with degrees you can multiply your angle by `DEGREES`, so the default camera orientation would be `self.set_camera_orientation(phi=0*DEGREES, theta=-90*DEGREES)`.

Things to try
– Play around with the angles `phi`, `theta`, and `gamma` to get a feel for how the camera is oriented
– Create a series of 2D mobjects and use the 3D camera to zoom around the mobjects.

12.0 Working with SVG Files

The PiCreatures in 3B1B are scalable vector graphics (svg) files. manim has an `SVGMobject` class that can import svg files. To play around with using svg images in manim, I've created a couple of figures using (Inkscape) [https://inkscape.org/en/], an open source vector graphics package. I wanted to try to make a stick figure wave in manim so I created two figures, one normal and one with the hand waving. You can get the svg files I've used at the end of this post. Place them in the `\media\designs\svg_images\` folder.

The code I used to import the stick figure was based on the PiCreature code located in [\manimlib\for_3b1b_videos\pi_creatures.py](). My code looks like:

```
HEAD_INDEX = 0
BODY_INDEX = 1
ARMS_INDEX = 2
LEGS_INDEX = 3

class StickMan(SVGMobject):
    CONFIG = {
        "color" : BLUE_E,
        "file_name_prefix": "stick_man",
        "stroke_width" : 2,
        "stroke_color" : WHITE,
        "fill_opacity" : 1.0,
        "height" : 3,
    }
    def __init__(self, mode = "plain", **kwargs):
        digest_config(self, kwargs)
        self.mode = mode
        self.parts_named = False
        try:
            svg_file = os.path.join(
                SVG_IMAGE_DIR,
                "%s_%s.svg" % (self.file_name_prefix, mode)
            )
            SVGMobject.__init__(self, file_name=svg_file, **kwargs)
```

```
        except:
            warnings.warn("No %s design with mode %s" %
                            (self.file_name_prefix, mode))
            svg_file = os.path.join(
                SVG_IMAGE_DIR,
                "stick_man_plain.svg",
            )
            SVGMobject.__init__(self, mode="plain", file_name=svg_file, **kwargs)


    def name_parts(self):
        self.head = self.submobjects[HEAD_INDEX]
        self.body = self.submobjects[BODY_INDEX]
        self.arms = self.submobjects[ARMS_INDEX]
        self.legs = self.submobjects[LEGS_INDEX]
        self.parts_named = True

    def init_colors(self):
        SVGMobject.init_colors(self)
        if not self.parts_named:
            self.name_parts()
        self.head.set_fill(self.color, opacity = 1)
        self.body.set_fill(RED, opacity = 1)
        self.arms.set_fill(YELLOW, opacity = 1)
        self.legs.set_fill(BLUE, opacity = 1)
        return self
```

I'm sure I could trim the code more but I just wanted something that would work without too much debugging. I've named the two files for the stick man as `stick_man_plain.svg` and `stick_man_wave.svg`. If you don't specify a mode when you instantiate the `StickMan` class, it will try load a file with the prefix specified in the CONFIG dictionary (in this example it is `stick_man`) and a suffix `_plain`. The `mode` variable can be used to specify related files. For example, the svg file with the stick man waving is called `stick_man_wave.svg` so if I specify the mode of `wave` this class will load that file. I can create an instance of the stick man using the waving figure using `StickMan("wave")`. Below is the code for the scene to make the stick man wave and you can find the svg files I used in my [Github repository here](#):

```
class Waving(Scene):
    def construct(self):
        start_man = StickMan()
        plain_man = StickMan()
        waving_man = StickMan("wave")

        self.add(start_man)
        self.wait()
        self.play(Transform(start_man,waving_man))
        self.play(Transform(start_man,plain_man))

        self.wait()
```

The reason I create two instances of the `StickMan()` is because I am transforming `start_man` but want the image to end up back looking like the original figure.

Two things to note. (1) The `stroke_width` and `stroke_color` for PiCreatures are set to not draw the outline of objects. If you want to see lines or the outlines of shapes you will need to set these values to something visible (i.e. non-zero `stroke_width` and a `stroke_color` that is different than the background). (2) Lines in svg are labeled as paths. The way manim deals with paths it to treat them as closed shapes. That means that if I don't set the `opacity` to zero for a line, I will see an enclosed shape. See the video below where I've set the `fill_opacity` in the `init_colors` method for everything to 1.

Although I haven't delved into the manim code, I think all manim looks at is the outlines of the shapes and not the filling.

I created a second scene just to make sure I had a handle on the scalable vector graphics import. When creating your own images, you will need to open the `.svg` file in a text editor to determine the indices for each submobject. manim imports each svg entity (e.g. a path, ellipse, box, or other shape) as a single submobject, and you will need to determine the ordering of those items in the parent SVGMobject class. I created a couple of shapes (a circle connected by lines to a pair of squares). The relevant part of the svg file for this is shown here (there is a lot more metadata in the file I left out):

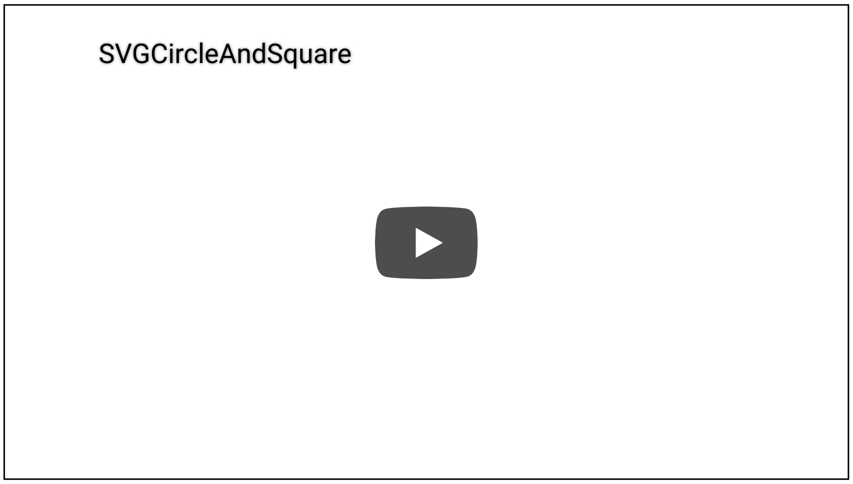
```
<br />
```

The file contains a circle, two paths, and two rectangles. Thus, when imported into manim, the circle will be the first submobject (index of 0), the two paths or lines will be the second and third submobject (indices 1 and 2) and the two squares will be the fourth and fifth submobject (indices 3 and 4). The class I used for this circle and square drawing is

```
class CirclesAndSquares(SVGMobject):
    CONFIG = {
        "color" : BLUE_E,
        "file_name_prefix": "circles_and_squares",
        "stroke_width" : 2,
        "stroke_color" : WHITE,
        "fill_opacity" : 1.0,
        "height" : 3,
        "start_corner" : None,
        "circle_index" : 0,
        "line1_index" :1,
        "line2_index" : 2,
        "square1_index" : 3,
        "square2_index" : 4,
    }
    def __init__(self, mode = "plain", **kwargs):
        digest_config(self, kwargs)
        self.mode = mode
        self.parts_named = False
        try:
            svg_file = os.path.join(
                SVG_IMAGE_DIR,
                "%s_%s.svg" % (self.file_name_prefix, mode)
            )
            SVGMobject.__init__(self, file_name=svg_file, **kwargs)
        except:
            warnings.warn("No %s design with mode %s" %
                          (self.file_name_prefix, mode))
            svg_file = os.path.join(
                SVG_IMAGE_DIR,
                "circles_and_squares_plain.svg",
            )
            SVGMobject.__init__(self, mode="plain", file_name=svg_file, **kwargs)


    def name_parts(self):
        self.circle = self.submobjects[self.circle_index]
        self.line1 = self.submobjects[self.line1_index]
        self.line2 = self.submobjects[self.line2_index]
        self.square1 = self.submobjects[self.square1_index]
        self.square2 = self.submobjects[self.square2_index]
        self.parts_named = True

    def init_colors(self):
        SVGMobject.init_colors(self)
        self.name_parts()
        self.circle.set_fill(RED, opacity = 1)
        self.line1.set_fill(self.color, opacity = 0)
        self.line2.set_fill(self.color, opacity = 0)
        self.square1.set_fill(GREEN, opacity = 1)
        self.square2.set_fill(BLUE, opacity = 1)
        return self
```

I've used the order of the different elements in the svg file to label the indices in my `CONFIG` dictionary at the start of the class. The code to display this on the screen is

```
class SVGCircleAndSquare(Scene):
    def construct(self):
        thingy = CirclesAndSquares()

        self.add(thingy)
        self.wait()
```



I know I can trim the code down for the svg class but I'll save that for another day.

The svg files can all be downloaded from here along with the tutorial file.

Posted in Just for Fun, Programming | Tagged animation, manim, Python | 54 Comments

Working with SVG Files – manim Series: Part 12

Posted on August 14, 2018

The post is part of a series on learning how to use manim. You can find the previous tutorial post in this series here and the overview of the entire series here.

Important Note: These posts are based on an earlier version of manim which uses Python 2.7. The latest version of manim is using Python 3. To follow along with these posts, use Python 2.7 and the May 9, 2018 commit of manim .

12.0 Working with SVG Files

The PiCreatures in 3B1B are scalable vector graphics (svg) files. manim has an `SVGMobject` class that can import svg files. To play around with using svg images in manim, I've created a couple of figures using (Inkscape) [https://inkscape.org/en/], an open source vector graphics package. I wanted to try to make a stick figure wave in manim so I created two figures, one normal and one with the hand waving. You can get the svg files I've used at the end of this post. Place them in the `\design\svg_images\` folder inside your media directory (the top level directory where all the animation subfolders get created).

The code I used to import the stick figure was based on the PiCreature code located in `\for_3b1b_videos\pi_creatures.py`. My code looks like:

```
class StickMan(SVGMobject):
CONFIG = {
"color" : BLUE_E,
"stroke_width" : 2,
"stroke_color" : WHITE,
"fill_opacity" : 1.0,
"propagate_style_to_family" : True,
"height" : 3,
"corner_scale_factor" : 0.75,
"flip_at_start" : False,
"is_looking_direction_purposeful" : False,
"start_corner" : None,
#Range of proportions along body where arms are
"right_arm_range" : [0.55, 0.7],
"left_arm_range" : [.34, .462],
}
def __init__(self, mode = "plain", **kwargs):
self.parts_named = False
try:
svg_file = os.path.join(
SVG_IMAGE_DIR,
"stick_man_%s.svg"%mode
)
SVGMobject.__init__(self, file_name = svg_file, **kwargs)
except:
warnings.warn("No StickMan design with mode %s"%mode)
svg_file = os.path.join(
SVG_IMAGE_DIR,
"stick_man.svg"
)
SVGMobject.__init__(self, file_name = svg_file, **kwargs)

if self.flip_at_start:
self.flip()
if self.start_corner is not None:
self.to_corner(self.start_corner)

def name_parts(self):
#self.mouth = self.submobjects[MOUTH_INDEX]
self.head = self.submobjects[HEAD_INDEX]
self.body = self.submobjects[BODY_INDEX]
self.arms = self.submobjects[ARMS_INDEX]
self.legs = self.submobjects[LEGS_INDEX]
self.parts_named = True

def init_colors(self):
SVGMobject.init_colors(self)
if not self.parts_named:
self.name_parts()
self.head.set_fill(RED, opacity = 0)
self.body.set_fill(self.color, opacity = 1)
self.arms.set_fill(YELLOW, opacity = 0)
self.legs.set_fill(GREEN, opacity = 0)
return self
```

I'm sure I could trim the code more but I just wanted something that would work without too much debugging. To animate the waving, I've used `get_all_pi_creature_modes` to load the file with the waving hand. To do this, the svg file with the wave must have a similar file name. In particular, if the original file is named `stick_man.svg`, the other file name needs to start with the same `stick_man` followed by an underscore and the name of the particular mode. Thus the figure with hand extended in a wave is called `stick_man_wave.svg`. I can create an instance of the stick man using the waving figure using `StickMan("wave")`. Below is the code for the scene to make the stick man wave.

```
class SVGStickMan(Scene):
def construct(self):
start_man = StickMan()
plain_man = StickMan()
waving_man = StickMan("wave")

self.add(start_man)
self.wait()
self.play(Transform(start_man,waving_man))
self.play(Transform(start_man,plain_man))
```

The reason I create two instances of the `StickMan()` is because I am transforming `start_man` but want the image to end up back looking like the original figure.

Two things to note. (1) The `stroke_width` and `stroke_color` for PiCreatures are set to not draw the outline of objects. If you want to see lines or the outlines of shapes you will need to set these values to something visible (i.e. non-zero `stroke_width` and a `stroke_color` that is different than the background). (2) Lines in svg are labeled as paths. The way manim deals with paths it to treat them as closed shapes. That means that if I don't set the `opacity` to zero for a line, I will see an enclosed shape. See the video below where I've set the `fill_opacity` in the `init_colors` method for everything to 1.

Although I haven't delved into the manim code, I think all manim looks at is the outlines of the shapes and not the filling.

I created a second scene just to make sure I had a handle on the scalable vector graphics import. When creating your own images, you will need to open the `.svg` file in a text editor to determine the indices for each submobject. manim imports each svg entity (e.g. a path, ellipse, box, or other shape) as a single submobject, and you will need to determine the ordering of those items in the parent SVGMobject class. I created a couple of shapes (a circle connected by lines to a pair of squares). The relevant part of the svg file for this is shown here (there is a lot more metadata in the file I left out):

```
<br />
```

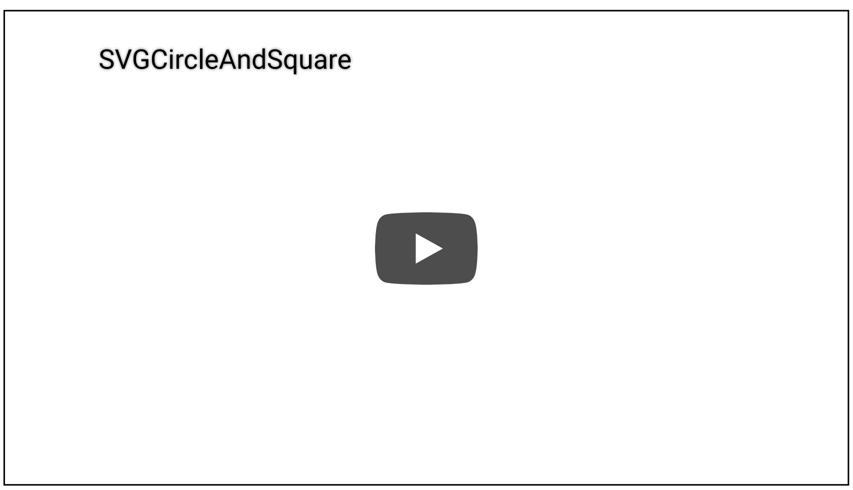
The file contains a circle, two paths, and two rectangles. Thus, when imported into manim, the circle will be the first submobject (index of 0), the two paths or lines will be the second and third submobject (indices 1 and 2) and the two squares will be the fourth and fifth submobject (indices 3 and 4). The class I used for this circle and square drawing is

```
class CirclesAndSquares(SVGMobject):
CONFIG = {
"color" : BLUE_E,
"stroke_width" : 2,
"stroke_color" : WHITE,
"fill_opacity" : 1.0,
"propagate_style_to_family" : True,
"height" : 3,
"corner_scale_factor" : 0.75,
"flip_at_start" : False,
"is_looking_direction_purposeful" : False,
"start_corner" : None,
"circle_index" : 0,
"line1_index" :1,
"line2_index" : 2,
"square1_index" : 3,
"square2_index" : 4,
}
def __init__(self, mode = "plain", **kwargs):
try:
svg_file = os.path.join(
SVG_IMAGE_DIR,
"circles_and_squares_%s.svg"%mode
)
SVGMobject.__init__(self, file_name = svg_file, **kwargs)
```

```
except:
warnings.warn("No other mode design with mode %s"%mode)
svg_file = os.path.join(
SVG_IMAGE_DIR,
"circles_and_squares.svg"
)
SVGMobject.__init__(self, file_name = svg_file, **kwargs)

def name_parts(self):
self.circle = self.submobjects[self.circle_index]
self.line1 = self.submobjects[self.line1_index]
self.line2 = self.submobjects[self.line2_index]
self.square1 = self.submobjects[self.square1_index]
self.square2 = self.submobjects[self.square2_index]
self.parts_named = True

def init_colors(self):
SVGMobject.init_colors(self)
self.name_parts()
self.circle.set_fill(RED, opacity = 1)
self.line1.set_fill(self.color, opacity = 0)
self.line2.set_fill(self.color, opacity = 0)
self.square1.set_fill(GREEN, opacity = 1)
self.square2.set_fill(BLUE, opacity = 1)
return self
```

I've used the order of the different elements in the svg file to label the indices in my `CONFIG` dictionary at the start of the class. The code to display this on the screen is

```
class SVGCircleAndSquare(Scene):
def construct(self):
thingy = CirclesAndSquares()

self.add(thingy)
self.wait()
```



I know I can trim the code down for the svg class but I'll save that for another day.

SVG Files

For some reason I'm not allowed to upload svg files to WordPress so I've included the full files here. Copy and paste each chunk of code into a separate text file and save it with a `.svg` extension). You can also find the files at https://github.com/zimmermant/manim_tutorial

stick_man.svg

```
<!--?xml version="1.0" encoding="UTF-8" standalone="no"?-->
<!-- Created with Inkscape (http://www.inkscape.org/) -->

image/svg+xml
```

stick_man_wave.svg

```
<!--?xml version="1.0" encoding="UTF-8" standalone="no"?-->
<!-- Created with Inkscape (http://www.inkscape.org/) -->

image/svg+xml
```

circles_and_squares.svg

```
<!--?xml version="1.0" encoding="UTF-8" standalone="no"?-->
<!-- Created with Inkscape (http://www.inkscape.org/) -->

image/svg+xml
```

Posted in Just for Fun, Programming | Tagged 3b1b, animation, manim, Python | 4 Comments

Fields of a Moving Charge – manim Series: Part 11

Posted on July 13, 2018

The post is part of a series on learning how to use manim. You can find the previous tutorial post in this series here and the overview of the entire series here.

Important Note: These posts are based on an earlier version of manim which uses Python 2.7. The latest version of manim is using Python 3. To follow along with these posts, use Python 2.7 and the May 9, 2018 commit of manim .

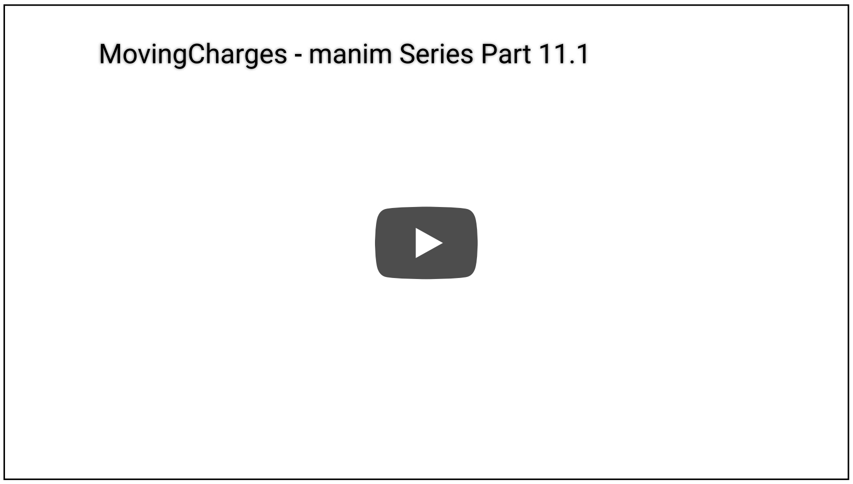
11.0 Field of a Moving Charge

There was a question over on Reddit about how to create the electric field of a moving charge. Since that is something I will want to do at some point I figured it would be fun to give it a try.

Before creating a changing field, I thought I'd start with moving charges around. I know I saw this in one of the videos so I can start with working code and modify it to my needs. Here is what I came up with:

```
class MovingCharges(Scene):
CONFIG = {
"plane_kwargs" : {
"color" : RED_B
},
"point_charge_loc" : 0.5*RIGHT-1.5*UP,
}
def construct(self):
plane = NumberPlane(**self.plane_kwargs)
plane.main_lines.fade(.9)
plane.add(plane.get_axis_labels())
self.add(plane)
```

```
field = VGroup(*[self.calc_field(x*RIGHT+y*UP)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
])
self.field=field
source_charge = self.Positron().move_to(self.point_charge_loc)
self.play(FadeIn(source_charge))
self.play(ShowCreation(field))
self.moving_charge()

def calc_field(self,point):
x,y = point[:2]
Rx,Ry = self.point_charge_loc[:2]
r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
efield = (point - self.point_charge_loc)/r**3
return Vector(efield).shift(point)

def moving_charge(self):
numb_charges = 1
possible_points = [v.get_start() for v in self.field]
points = random.sample(possible_points, numb_charges)
particles = VGroup(*[
self.Positron().move_to(point)
for point in points
])
for particle in particles:
particle.velocity = np.array((0,0,0))

self.play(FadeIn(particles))
self.moving_particles = particles
self.add_foreground_mobjects(self.moving_particles )
self.always_continually_update = True
self.wait(10)

def field_at_point(self,point):
x,y = point[:2]
Rx,Ry = self.point_charge_loc[:2]
r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
efield = (point - self.point_charge_loc)/r**3
return efield

def continual_update(self, *args, **kwargs):
if hasattr(self, "moving_particles"):
dt = self.frame_duration
for p in self.moving_particles:
accel = self.field_at_point(p.get_center())
p.velocity = p.velocity + accel*dt
p.shift(p.velocity*dt)

class Positron(Circle):
CONFIG = {
"radius" : 0.2,
"stroke_width" : 3,
"color" : RED,
"fill_color" : RED,
"fill_opacity" : 0.5,
}
def __init__(self, **kwargs):
Circle.__init__(self, **kwargs)
plus = TexMobject("+")
plus.scale(0.7)
plus.move_to(self)
self.add(plus)
```



The most important method here is `continual_update()`. This method updates the screen for each frame during the entire scene. This differs from the various transformations that rely on the `play()` method in that the transformations occur over a short time interval, usually on the order of a few seconds while the continual methods continue to run for the entire scene. If we want a particle to move across the screen we might be tempted to use something like `self.play(ApplyMethod(particle1.shift,5*LEFT))` but it would be challenging to control the timing of other transformations going on at the same time. The `continual_update()` allows you to animate things in the background while still controlling the timing of other transformations.

Since I know I will be using charged particles in my videos I've written a `Positron` class to create positively charged particles. The positron is the positive antiparticle of the electron. Why didn't I make it a proton? Because the proton is roughly 2000 times more massive and I want similarly sized particles for what I want to do.

We've reused the code from a previous post about electric fields but we've added methods to create the charged particles and move them around. `moving_charge()` is what creates positrons by randomly selecting a field point (`possible_points = [v.get_start() for v in self.field]` is a list of the locations of the tails of all field vectors) and then selects `numb_charges` points to create particles at. Note that the randomly generated charges don't react to one another, which I find disturbing to watch because it isn't physical.

`particles` is a vectorized mobject group that contains all of the moving charges with initial velocities set to zero (`particle.velocity = np.array((0,0,0))`). We could have simplified the code by only using one particle at a set location, but we'll need multiple charges later on. The charges are then added to the screen (`self.play(FadeIn(particles)`) and assigned to a class variable that is needed in `continual_update` (`self.moving_particles = particles`). Mobjects are drawn in the order they are added to the screen but you can place certain mobjects in the foreground to insure they always remain drawn on top of other objects by using `add_foreground_mobjects()`. It is kind of like layers in Photoshop or similar software except each mobject is in its own layer. This has to do with the fact that manim keeps all mobjects drawn on the screen in a list and draws them in the order they are listed. There is no equivalent background mobject method, but you can send mobjects to the front or back layers with `bring_to_front()` and `bring_to_back()`.

Next we tell manim to continually update things in the background (`self.always_continually_update = True`) and then wait ten seconds. It is important to set the `wait()` command because the continual update only runs as long as their are animation elements (`play()` commands) or `wait()` commands in the animation queue.

The `field_at_point()` method duplicates some of the earlier code but is used to return a numerical vector (a numpy 3-element array) rather than a mobject `Vector`, which is what `calc_field()` returns. It took me an embarassing amount of time to figure out why I couldn't just use `calc_field()` to find the force vector.

The `continual_update()` method is called each frame when the scene is being composed. The first line, `if hasattr(self, "moving_particles"):` prevents the rest of the code running and throwing and error if you haven't created `self.moving_particles`. The frame duration is either 1/15, 1/30, or 1/60 of a second, depending on whether your video is low, medium, or production quality (i.e. whether you include -l, -m, or no command line argument when extracting the scene). We run through the list of all moving particles (`for p in self.moving_particles:`) and then calculate the acceleration due to the electric field at the location of each particle (`vect = self.field_at_point(p.get_center())`). `p.get_center()` returns the vector location of each particle `p`. The velocity is updated using $\vec{v}_f = \vec{v}_i + a\Delta t$ and then the particle is shifted over the distance $\vec{v}_f\Delta t$.

11.1 Updating the Electric Field of a Moving Charge

Now we've got some experience moving things around on the screen so we can move on to calculating the field due to the particle. We will reuse much of the code from our previous program, with a few changes.

```
class FieldOfMovingCharge(Scene):
CONFIG = {
"plane_kwargs" : {
"color" : RED_B
},
"point_charge_start_loc" : 5.5*LEFT-1.5*UP,
}
def construct(self):
plane = NumberPlane(**self.plane_kwargs)
plane.main_lines.fade(.9)
plane.add(plane.get_axis_labels())
self.add(plane)

field = VGroup(*[self.create_vect_field(self.point_charge_start_loc,x*RIGHT+y*UP)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
])
self.field=field
self.source_charge = self.Positron().move_to(self.point_charge_start_loc)
self.source_charge.velocity = np.array((1,0,0))
self.play(FadeIn(self.source_charge))
self.play(ShowCreation(field))
self.moving_charge()

def create_vect_field(self,source_charge,observation_point):
return Vector(self.calc_field(source_charge,observation_point)).shift(observation_poi

def calc_field(self,source_point,observation_point):
x,y,z = observation_point
Rx,Ry,Rz = source_point
r = math.sqrt((x-Rx)**2 + (y-Ry)**2 + (z-Rz)**2)
if r<0.0000001: #Prevent divide by zero
efield = np.array((0,0,0))
else:
efield = (observation_point - source_point)/r**3
return efield

def moving_charge(self):
```

```
numb_charges=1
possible_points = [v.get_start() for v in self.field]
points = random.sample(possible_points, numb_charges)
particles = VGroup(self.source_charge, *[
self.Positron().move_to(point)
for point in points
])
for particle in particles[1:]:
particle.velocity = np.array((0,0,0))
self.play(FadeIn(particles[1:]))
self.moving_particles = particles
self.add_foreground_mobjects(self.moving_particles )
self.always_continually_update = True
self.wait(5)

def continual_update(self, *args, **kwargs):
Scene.continual_update(self, *args, **kwargs)
if hasattr(self, "moving_particles"):
dt = self.frame_duration

for v in self.field:
field_vect=np.zeros(3)
for p in self.moving_particles:
field_vect = field_vect + self.calc_field(p.get_center(), v.get_start())
v.put_start_and_end_on(v.get_start(), field_vect+v.get_start())

for p in self.moving_particles:
accel = np.zeros(3)
p.velocity = p.velocity + accel*dt
p.shift(p.velocity*dt)

class Positron(Circle):
CONFIG = {
"radius" : 0.2,
"stroke_width" : 3,
"color" : RED,
"fill_color" : RED,
"fill_opacity" : 0.5,
}
def __init__(self, **kwargs):
Circle.__init__(self, **kwargs)
plus = TexMobject("+")
plus.scale(0.7)
plus.move_to(self)
self.add(plus)
```

FieldOfMovingCharge - manim Series Part 11.2

One change we've made is to let `calc_field()` return a numpy vector rather than a mobject `Vector`. This does mean adding in `create_vect_field()` to create the mobjects from the numpy vectors.

Since we want our source charge to be able to move we have to add that source charge to the `particles` list. Thus the Vgroup we create includes that source charge plus the randomly generated charges using `particles = VGroup(self.source_charge, *[self.Positron().move_to(point) for point in points])`. Remember that the asterisk in front of the list lets Python know that each element in the list should be broken out and treated as a separate argument for the `VGroup()` class. To help make sense of this line of code we can break it out into a less elegant form:

```
list_of_random_charges=[]
for point in points:
new_charge = self.Positron().move_toe(point)
list_of_random_charges.append(new_charge)
particles = VGroup(self.source_charge, list_of_random_charges[0], list_of_random_charg
```

Thus one line of code replaces several lines. The reason we use `particles[1:]` in the code defining the velocity and fading in the particles is that the source charge already has a velocity and is on screen so we don't want to redefine the velocity or have it fade in again (which makes it blink).

In `continual_update()` we now need to calculate the field at each grid point at each time step. First we cycle through each field point (`for v in self.field:`). Since we want to add up the fields from several charges, we set the field vector to zero (`field_vect=np.zeros(3)`) and then add up the fields at that point due to each charge (`field_vect = field_vect + self.calc_field(p.get_center(), v.get_start())`). We need to redraw the field vectors by specifying the start and end points of the vector. The start point is the initial grid point where the vector starts (`v.get_start()`) and the tip of the arrow is a distance equal to the field vector plus the starting point (`field_vect+v.get_start()`).

I don't have the particles react to the fields of the other particles. This looks very unrealistic to me but it should be easy enough to implement. I just wanted to put out a post that lays out the basics of how to get the field lines working.

As usual, the code can be found at https://github.com/zimmermant/manim_tutorial.

[Next time](#) I'll look at how to work with SVG files in manim.

Posted in Just for Fun, Programming | Tagged 3b1b, animation, manim, Python | 4 Comments

3D Scenes – manim Series: Part 10

Posted on July 3, 2018

The post is part of a series on learning how to use manim. You can find the previous tutorial post in this series [here](#) and the overview of the entire series [here](#).

Note: When extracting these scenes I'd recommend including the low quality command line argument `l`. These scenes can take several minutes to extract at higher qualities.

Important Note: These posts are based on an earlier version of manim which uses Python 2.7. The latest version of manim is using Python 3. To follow along with these posts, use Python 2.7

and the [May 9, 2018 commit of manim .]

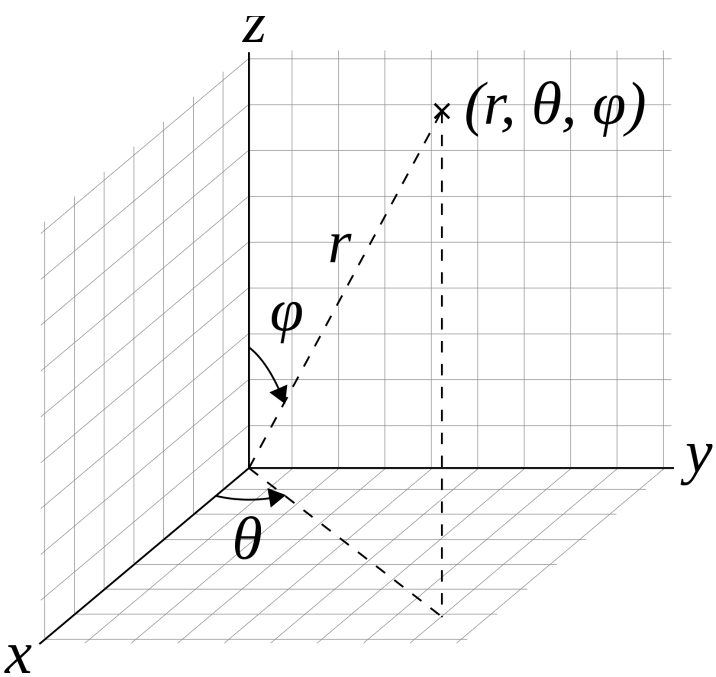
10.0 3D Scenes

The 3D scenes really aren't any different than 2D scenes except you can now move the camera around using `self.move_camera()`. Below is an example using the 2D vector field from my previous post.

```
class ExampleThreeD(ThreeDScene):
CONFIG = {
"plane_kwargs" : {
"color" : RED_B
},
"point_charge_loc" : 0.5*RIGHT-1.5*UP,
}
def construct(self):
self.set_camera_position(0, -np.pi/2)
plane = NumberPlane(**self.plane_kwargs)
plane.main_lines.fade(.9)
plane.add(plane.get_axis_labels())
self.add(plane)

field2D = VGroup(*[self.calc_field2D(x*RIGHT+y*UP)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
])

self.play(ShowCreation(field2D))
self.wait()
self.move_camera(0.8*np.pi/2, -0.45*np.pi)
self.begin_ambient_camera_rotation()
self.wait(6)

def calc_field2D(self,point):
x,y = point[:2]
Rx,Ry = self.point_charge_loc[:2]
r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
efield = (point - self.point_charge_loc)/r**3
return Vector(efield).shift(point)
```

The differences between this code and the example from my previous post is (1) the parent class is `ThreeDScene` rather than `Scene`, (2) the `self.set_camera_position()` command, (3) the `self.move_camera()` command, and (4) the `self.begin_ambient_camera_rotation()` command.

The `ThreeDScene()` adds the ability to change the orientation of the camera. `set_camera_position()` moves the camera to the specified location and orientation. The camera will abruptly jump to the given location. If we want a smooth camera transition (panning the camera) we'd use `move_camera()`. The keyword arguments for `set_camera_position()` are `phi`, `theta`, `distance`, `center_x`, `center_y`, and `center_z`. The point that the camera is pointing towards is given by `center_x`, `center_y`, `center_z`. The other three arguments correspond to ϕ, θ, and r in the figure below. Notice that the center point corresponds to the origin of the graph, with the camera located at the 'x', looking back towards the origin. This is why $\phi = 0$ and $\theta = -\pi/2$ corresponds to the normal 2D orientation with the x-axis pointing right and the y-axis pointing up on the screen. If you set $\theta = \pi/2$ we flip the screen over.



By Dmcq – Own work, CC BY-SA 3.0, Link

10.1 3D Vector Field

Drawing a three-dimensional vector field requires only a couple of tweaks to our original code. We will copy the code for `field2D` and the method `calc_field2D` to create `field3D` and `calc_field3D`. With `field3D` we need to only add `for z in np.arange(-5,5,1)` and then send the vector `x*RIGHT + y*UP + z*OUT` to `calc_field3D`. Next we add the z-coordinates to `calc_field3D`. This means we don't slice `point` or `self.point_charge` since we need all three components. We also need to add `(z-Rz)**2` to the equation for `r`.

```
class EFieldInThreeD(ThreeDScene):
CONFIG = {
"plane_kwargs" : {
"color" : RED_B
},
"point_charge_loc" : 0.5*RIGHT-1.5*UP,
}
def construct(self):
self.set_camera_position(0.1, -np.pi/2)
plane = NumberPlane(**self.plane_kwargs)
plane.main_lines.fade(.9)
plane.add(plane.get_axis_labels())
self.add(plane)

```

```
field2D = VGroup(*[self.calc_field2D(x*RIGHT+y*UP)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
])

field3D = VGroup(*[self.calc_field3D(x*RIGHT+y*UP+z*OUT)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
for z in np.arange(-5,5,1)])

self.play(ShowCreation(field3D))
self.wait()
self.move_camera(0.8*np.pi/2, -0.45*np.pi)
self.begin_ambient_camera_rotation()
self.wait(6)

def calc_field2D(self,point):
x,y = point[:2]
Rx,Ry = self.point_charge_loc[:2]
r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
efield = (point - self.point_charge_loc)/r**3
return Vector(efield).shift(point)

def calc_field3D(self,point):
x,y,z = point
Rx,Ry,Rz = self.point_charge_loc
r = math.sqrt((x-Rx)**2 + (y-Ry)**2+(z-Rz)**2)
efield = (point - self.point_charge_loc)/r**3
return Vector(efield).shift(point)
```

We don't need `field2D` or `calc_field2D` anymore but I left them in for comparison to the updated code.

Things to try

– Rotate the camera so it is below the axes and to the left (or any other point you choose)

– Try plotting a different vector field

– Plot a constant field

– Try efield = np.array((-y,x,z))/math.sqrt(x**2+y**2+z**2)

– Come up with your own 3D vector field

Check out the [next post in this series](#) where we look at how to animate the electric field of a moving charge.

Posted in Just for Fun, Programming | Tagged 3b1b, animation, manim, Python | 3 Comments

Matter & Interactions Section Headings

Posted on July 2, 2018

I was looking for the section headings for volume 2 of the 4th edition of Matter & Interactions and couldn't find them online. Since texts tend to be online these days page numbers don't matter as much as section titles. I sat down and typed them all in and I thought I'd post this here in case anyone else needed them.

Section_Titles_M_and_I_4th

Posted in Teaching Physics | Tagged Matter&Interaction | Leave a comment

Vector Fields – manim Series: Part 9

Posted on June 27, 2018

The post is part of a series on learning how to use manim. You can find the previous tutorial post in this series here and the overview of the entire series here.

Important Note: These posts are based on an earlier version of manim which uses Python 2.7. The latest version of manim is using Python 3. To follow along with these posts, use Python 2.7 and the May 9, 2018 commit of manim .

9.0 Vector Fields

Before diving into draw a vector field, we should set up a Cartesian axes using `NumberPlane()`. This gives you two axes and an underlying grid. The `CONFIG{}` for the `NumberPlane()` class is

```
class NumberPlane(VMobject):
CONFIG = {
"color": BLUE_D,
"secondary_color": BLUE_E,
"axes_color": WHITE,
"secondary_stroke_width": 1,
"x_radius": None,
"y_radius": None,
"x_unit_size": 1,
"y_unit_size": 1,
"center_point": ORIGIN,
"x_line_frequency": 1,
"y_line_frequency": 1,
"secondary_line_ratio": 1,
"written_coordinate_height": 0.2,
"propagate_style_to_family": False,
"make_smooth_after_applying_functions": True,
}
```

You can change any of these default values by passing a dictionary with new values as keyword arguments. For example, if you want to change the spacing of the grid lines you could change `x_line_frequency` and `y_line_frequency` by defining a dictionary with these variables and then passing the dictionary to `NumberPlane()`. If you want to see the x-axis and y-axis indicated you can use `get_axis_labels()` to draw an `x` and a `y` next to the appropriate axis. See the code below.

```
class DrawAnAxis(Scene):
```

```
CONFIG = { "plane_kwargs" : {
"x_line_frequency" : 2,
"y_line_frequency" :2
}
}

def construct(self):
my_plane = NumberPlane(**self.plane_kwargs)
my_plane.add(my_plane.get_axis_labels())
self.add(my_plane)
self.wait()
```

The double asterisk in front of the argument `self.plane_kwargs` lets the class know that this is a dictionary that needs to be unpacked.

I recommend changing the various properties to see what affect they have on the axes and grid. This is the best way to learn what things do.

9.1 A Simple Vector Field

Let's start with a simple vector field; a constant field. We first need to define a set of vector points for each grid point, define the field at each grid point, then create the `Vector()` for the field at each point. Finally we combine all the `Vector()` instances into a `VGroup` to allow us to draw all vector lines with a single command.

```
class SimpleField(Scene):
CONFIG = {
"plane_kwargs" : {
"color" : RED
},
}
def construct(self):
plane = NumberPlane(**self.plane_kwargs) #Create axes and grid
plane.add(plane.get_axis_labels()) #add x and y label
self.add(plane) #Place grid on screen

points = [x*RIGHT+y*UP
for x in np.arange(-5,5,1)
for y in np.arange(-5,5,1)
] #List of vectors pointing to each grid point

vec_field = [] #Empty list to use in for loop
for point in points:
field = 0.5*RIGHT + 0.5*UP #Constant field up and to right
```

```
result = Vector(field).shift(point) #Create vector and shift it to grid point
vec_field.append(result) #Append to list

draw_field = VGroup(*vec_field) #Pass list of vectors to create a VGroup

self.play(ShowCreation(draw_field)) #Draw VGroup on screen
```

After creating the `NumberPlane()` we use a list comprehension to create a list of the location of all grid points. Remember that `RIGHT=np.array(1,0,0)` and `UP=np.array(0,1,0)` so this list comprehension covers all points from (5,5,0) down to (-5,-5,0) in unit step sizes. The last number in `arange()` specifies the step size. Next we create an empty list `vec_field` to hold all of the vectors we are going to create. The `for` loop goes through each grid location in `points` and creates a vector whose length and direction are defined by `field`. It is inefficient to keep defining `field` each time through the loop but we are setting things up for later. The `shift(point)` command moves the vector to the grid location defined by `point`. These results are then appended to a list. After going through the `for` loop. all of the vectors are grouped together in a single `VGroup` called `draw_field`. The only reason for doing this is that you can then add `draw_field` using a single `add` or `play` command. You could have included `self.add(result)` inside each iteration of the `for` loop instead of showing the creation of `draw_field`, but using the `VGroup` feels cleaner.

9.2 A Variable Vector Field

For a slightly more interesting field we will look at the electric field due to a postive point charge. The electric field is:

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^3}\vec{r}$$

where q_1 is the charge on the point charge, $\vec{r}$ is the distance vector between the charge and the observation point, and r is the magnitude of that vector. The constant out front $\frac{1}{4\pi\epsilon_0} = 9\times10^9 Nm^2/C^2$ is essentially a conversion factor. For our purposes we will set all constants equal to zero and just look at

$$\vec{E} = \frac{1}{r^3}\vec{r}.$$

```
class FieldWithAxes(Scene):
CONFIG = {
"plane_kwargs" : {
"color" : RED_B
},
"point_charge_loc" : 0.5*RIGHT-1.5*UP,
```

```
}
def construct(self):
plane = NumberPlane(**self.plane_kwargs)
plane.main_lines.fade(.9)
plane.add(plane.get_axis_labels())
self.add(plane)

field = VGroup(*[self.calc_field(x*RIGHT+y*UP)
for x in np.arange(-9,9,1)
for y in np.arange(-5,5,1)
])

self.play(ShowCreation(field))

def calc_field(self,point):
x,y = point[:2]
Rx,Ry = self.point_charge_loc[:2]
r = math.sqrt((x-Rx)**2 + (y-Ry)**2)
efield = (point - self.point_charge_loc)/r**3
```

The location of the point charge is set in `CONFIG{}`. To create the vector field we've condensed the previous code. We use a list comprehension and the function `calc_field()` as the argument of `VGroup()`. The `calc_field()` function defines the field to calculate. To make the formulas a little easier to read we unpack the x- and y-coordinates from the `point` vector and the `self.point_charge_loc` vector. The code `x,y=point[:2]` is equivalent to `x=point[0]` and `y=point[1]`.

The `fade(0.9)` method sets the opacity of the lines to be one minus the fade level (so in this case the opacity is set to 0.1). This was done to make it easier to see the tiny field arrows farther from the charge location.

Things to try:

– Change each of the elements in `CONFIG{}` for `NumberPlane()` to see what affect they have on the axes and grid lines.
– Calculate different fields
– Try `efield = np.array((-y,x,0))/math.sqrt(x**2+y**2)`
– Try `efield = np.array(( -2*(y%2)+1 , -2*(x%2)+1 , 0 ))/3`
– Come up with your own equation

Note: If you end up creating a video using manim and post it online, please link to it in the comments. I'm sure everyone would love to see what sort of fun things everyone is doing.

[Next time](#) we will look at plotting vector fields in three dimensions.

Posted in Just for Fun, Programming | Tagged 3b1b, animation, manim, Python | 7 Comments

More Graphing – manim Series: Part 8

Posted on June 25, 2018

The post is part of a series on learning how to use manim. You can find the previous tutorial post in this series here and the overview of the entire series here.

Important Note: These posts are based on an earlier version of manim which uses Python 2.7. The latest version of manim is using Python 3. To follow along with these posts, use Python 2.7 and the May 9, 2018 commit of manim .

8.0 More Graphing

In the previous post in this series we looked at how to graph functions in manim so go take a look at this if you haven't already. I've been playing a bit more with graphing in manim and wanted to share some of what I've learned. You can copy and paste the code below or download the code from Github.

```
class ExampleApproximation(GraphScene):
CONFIG = {
"function" : lambda x : np.cos(x),
"function_color" : BLUE,
"taylor" : [lambda x: 1, lambda x: 1-x**2/2, lambda x: 1-x**2/math.factorial(2)+x**4/
lambda x: 1-x**2/math.factorial(2)+x**4/math.factorial(4)-x**6/math.factorial(6)+x**8
"center_point" : 0,
"approximation_color" : GREEN,
"x_min" : -10,
"x_max" : 10,
"y_min" : -1,
"y_max" : 1,
"graph_origin" : ORIGIN ,
"x_labeled_nums" :range(-10,12,2),

}
def construct(self):
self.setup_axes(animate=True)
func_graph = self.get_graph(
self.function,
self.function_color,
)
approx_graphs = [
self.get_graph(
f,
self.approximation_color
)
for f in self.taylor
]

term_num = [
TexMobject("n = " + str(n),aligned_edge=TOP)
for n in range(0,8)]
[t.to_edge(BOTTOM,buff=SMALL_BUFF) for t in term_num]

term = TexMobject("")
term.to_edge(BOTTOM,buff=SMALL_BUFF)

approx_graph = VectorizedPoint(
```

```
self.input_to_graph_point(self.center_point, func_graph)
)

self.play(
ShowCreation(func_graph),
)
for n,graph in enumerate(approx_graphs):
self.play(
Transform(approx_graph, graph, run_time = 2),
Transform(term,term_num[n])
)
self.wait()
```

I wanted to demonstrate how adding higher terms in a Taylor expansion results in better and better agreement with a function. This is similar to what shinigamiphoenix posted [here](#).

The functions to plot are defined as lambda functions in the `CONFIG{}` dictionary. manim processes all elements in `CONFIG{}` and turns the dictionary entries into class variables with the key as the variable name. Thus `"function"` can be accessed within my class by calling `self.function` and `"taylor"` can be called with `self.taylor`. If you aren't familiar with lambda functions, check out [this](#) post at [Python Conquers the Universe](#).

We create a list of graphs using `get_graph()` and a list comprehension. You can find a nice tutorial on list comprehensions over at [datacamp.com](#). It was only after reading this tutorial that I made the connection between list comprehensions and mathematical notation for definitions of sets (e.g. the set of positive real numbers is$\{x|x \in \text{R and } x > 0\}$ or the set of even numbers which is $\{x|x \in \text{I and } x \; mod(2) = 0\}$), which made list comprehensions click for me. For each item in the list `self.taylor`, a graph is created with color `self.approximation_color`. We also created a list of TexMobjects to indicate which order of terms are included from the Taylor expansion using a list comprehension.

Since we are going to do successive transformations from a list, it helps to have a blank placeholder on the screen. `term` and `approx_graph` are `VectorizedPoint` instances, which are mobjects that don't display anything on screen. This way we can put the placeholders on the screen without anything appearing, and then transform those mobjects into either the graph or the TexMobjects.

The `enumerate()` command is a useful tool that iterates over a list and also returns the index of the item returned. Thus `for n,graph in enumerate(approx_graphs)` returns the index between 0 and 4 as `n`, and the element within the list as `graph`. This is used to display the corresponding item from `term_num` with each graph.

Check out how to draw vector fields in the next post in this series.

Posted in Just for Fun, Programming | Tagged 3b1b, animation, manim, Python | 4 Comments