DRAWING WORDS WITH EQUATIONS

A MATHEMATICAL EXPLORATION OF THE MALAYALAM SCRIPT

Jasmine Jacob

At first glance, Figure 1 might look impossible to graph using simple graphing features, with its looping curves, overlapping points, and almost knot-like structure. It looks more like an abstract art piece than the script of a language spoken by 35 million people worldwide[1]or even something that can be described by graphical equations! To someone unfamiliar with the script, it may look very random.

But is it?

Malayalam is a Dravidian script, used on the western coast (the Malabar) in South India. Since I have known how to read and write this language since the age of 9, I have had time for the script to become second nature to me, whilst also considering whether the script letters are as free flowing as they appear, or is there some sort of underlying mathematical structure…

Figure 1 actually shows some of the letters from the Malayalam alphabet. Many of which are built from smooth curves, giving them a curvilinear structure – making some of them ideal for mathematical modelling. This allowed me to raise the simple question: can you graph a language?

Figure 1

In this essay, I will be describing and explaining the process of writing up a simple phrase in Malayalam on GeoGebra. With this, I hope to see whether mathematics has the capability to emulate the handwritten language, and where it falls short.

To begin modelling the script, I decided against writing out the entire alphabet and chose to graph a simple phrase that would be written on paper in one line. This phrase will be translated towards the end of the essay, so stay tuned! In Malayalam, the phrase was "ടോം റോക്സ് മാത്സ്".

[1] https://plc.sas.upenn.edu/languages/malayalam

I then started off by eyeballing the sizes and dimensions of each character, and I shall tell you all something now: do not do this – I learned this the wrong way. GeoGebra and other graphing systems have effectively continuous resolution, so however much you zoom in/out, the small grid squares change constantly, revealing that characters which seem proportionate at one scale may not remain so when examined more precisely. As seen in figure 2, it is very obvious that the scaling here is atrocious – working to 4 decimal places to form a circumcircular arc is extravagant. Although the idea behind this method is valid, it quickly becomes unnecessarily complicated. It involves using Pythagoras' theorem to calculate distances between points, forming ratios with the main body of the character, and then applying these to recreate arcs elsewhere. While mathematically sound, this level of detail proved redundant for the purpose of this model. I was sure there was something much simpler that could be done to create a symmetrical shape. When I wrote out the word "symmetry", the first thing I thought about was lines of symmetry – a very simple topic taught at secondary school. This very simple concept would allow us to get perfect symmetry for the characters they are needed for.

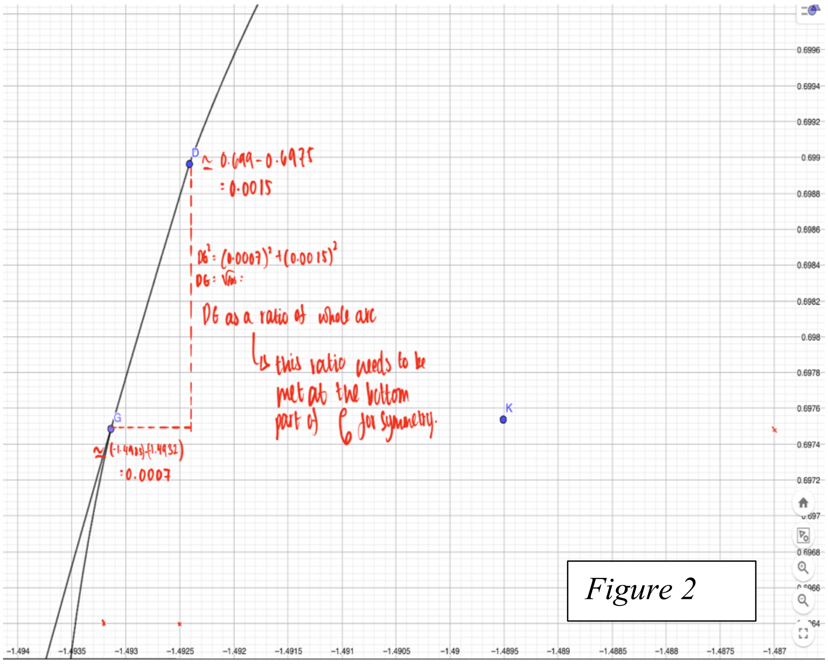


Figure 2

But before this, I think it is a good idea to explain the curvature of the Malayalam script. A lot of the South Indian Dravidian language scripts consist of curved characters, whereas scripts like Latin, Greek, and even Hindi have more straight and angular characters. This has a lot to do with the history of the way the language was written. It was written using palm leaves which had the characters carved on with a stylus and then stained with charcoal. If these characters were any straighter, the palm leaf (the surface used at the time of making) would have ripped, and the Malayalam script would not be as mathematically interesting as it is today! With its curvature and loops, Malayalam is known to be an aesthetically pleasing language to look at; mathematics provides a way to analyse and describe this structure more precisely. The Golden Ratio is often used to improve the aesthetics of a product by rendering it to dimensions which look leasing to the human eye. The formula for the Golden Ratio is shown in Figure 3.

$$\phi = \frac{1+\sqrt{5}}{2}$$

Figure 3

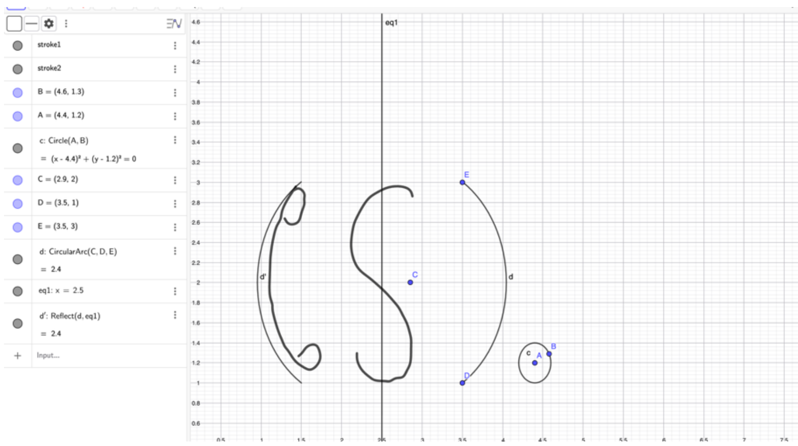
With some characters like "ഉ" it might look like this ratio is used but the Malayalam script wasn't designed with the intent of following a similar structure of the Fibonacci spiral, and as a result, I thought it would be redundant to use this in the graphing of the phrase – since this level of precision or mathematical principles is used in the traditional print script and the point of this investigation is to see if it is possible to graph the phrase with the simplest possible equations!

To begin with the simple equations, the simplest we can use to actually graph a character is a circle, whose equation is written in the form

$$(\boldsymbol{x} - \boldsymbol{a})^2 + (\boldsymbol{y} - \boldsymbol{b})^2 = \boldsymbol{r}^2$$

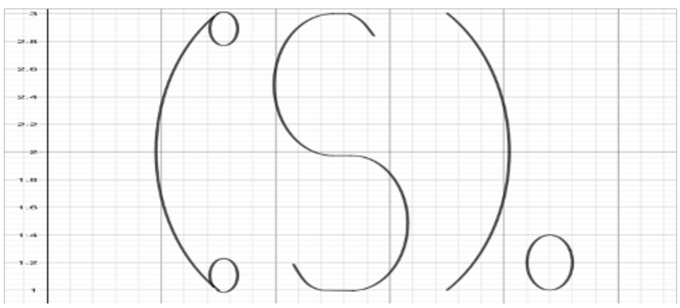
where (a,b) is the centre
and r is the radius.

Since this equation was used for the Anuswaram (a nasalised syllable that comes at the end of a word) "ം" I had to make this character significantly smaller than the maximum height of the main characters (which I decided to be 2 units in the y-direction). Although I said eyeballing wasn't a good idea, I had to for this because in a lot of fonts, this Anuswaram is much bigger than the smaller curves on a bigger character, meaning they can't be half or even a quarter of the height of the characters. With this process of trial-and-error of seeing what size of the Anuswaram works, I finally got a circle that looked well proportionate to the other



characters in the word "ടോം". With the aid of the freehand tool, I could draw out the shape of the first character so I could emulate it using a circumcircular arc, which mimics the shallow curve used in the vowel. I then used a circumcircular arc at the top of one end of the arc. To avoid the issue encountered with the attempt of a Pythagorean ratio earlier, I used a simple reflection of the circumcircular arc about $\boldsymbol{y} = \mathbf{2}$ to get the identical shape in the identical opposite position on the character.

The character to the right of the "ട" shape has a similar shape to the first character, and so I decided to use a simple reflection about $\boldsymbol{x} = \mathbf{2.5}$. A very similar concept was used in the base consonant "ട". However, I also used semicircles and line segments to extend the ends of the character whilst also ensuring it fits within the maximum height specified. Using these and a few reflections, I finally got my first word!



The second word was "റോക്സ്" which thankfully has some now familiar characters but also invites us for some interesting maths with "ക്" that could get us knotted up (pun intended!) with elipses, segments and semicircles. However, the first unfamiliar character seen is "റ" which is another consonant. With its parabolic shape it would have been an ideal shape to graph with an infinite graph, or even with parametric equations (which could be for another day since there is already a lot of different maths concepts going into this right now). But considering that I want to graph this phrase using the simple tools available on GeoGebra, I persevered. While symmetry and circular arcs worked well for the more regular parts of the characters, not all curves followed such predictable shapes. Some strokes were far more irregular, flowing in a way that could not be easily captured by a single equation. To model these sections, I turned to splines.

A spline is a smooth curve that passes through a set of chosen points, allowing the overall shape to be guided rather than strictly defined. Instead of forcing the curve to follow a fixed geometric form, splines adapt to the natural flow of the character by connecting multiple points with continuous, smooth transitions. This makes them particularly effective for modelling handwriting, where curves are determined more by motion than by strict mathematical rules.

In this case, I selected key points (V, T' and W) along the more complex strokes of each character and used splines to interpolate between them. I had to enter it in the form:

$$a = \text{Spline}(\{V, T, W\}, 3)$$

$$= \left.\begin{aligned} x &= \text{If}\left(t < 0.5, 0\,t^3 + 0.4\,t + 7.8, 0\,t^3 + 0\,t^2 + 0.4\,t + 7.8\right) \\ y &= \text{If}\left(t < 0.5, -0.3\,t^3 + 0.3\,t + 2.9, 0.4\,t^3 - 1.1\,t^2 + 0.8\,t + 2.9\right) \end{aligned}\right\} 0 \le t \le 1$$

This allowed the graph to follow the intended shape much more closely than circular arcs alone. However, this added flexibility comes at a cost. Unlike arcs, which can be described neatly with a single equation, splines rely on multiple segments and are less straightforward to express algebraically. As a result, while they improved the visual accuracy of the model, they also highlighted a trade-off between mathematical simplicity and the ability to capture the true fluidity of the script. Thus, allowing me to find some fluidity within the strict mathematical equations.

After figuring out how to use the spline tool, I flew through graphing “ക്”, using the following equations:

$s: \text{Ellipse}(A_1, B_1, C_1)$
$= 16.1x^2 - 0.1x\,y + 7.8y^2 - 369.4x - 29.6y = -2145.7$

$D_1 = \text{Point}(f)$
$= (10.4, 2)$

$E_1 = (12.6, 2)$

$l = \text{Segment}(D_1, E_1)$
$= 2.2$

$F_1 = \text{Point}(l)$
$= (12.5, 2)$

$G_1 = (12.5, 1.2)$

$t: \text{Semicircle}(F_1, G_1)$
$= 1.2$

$H_1 = (10.3, 1.9)$

$J_1 = \text{Point}(s)$
$= (11, 1.3)$

$c_1: \text{CircumcircularArc}(D_1, H_1, J_1)$
$= 1.3$

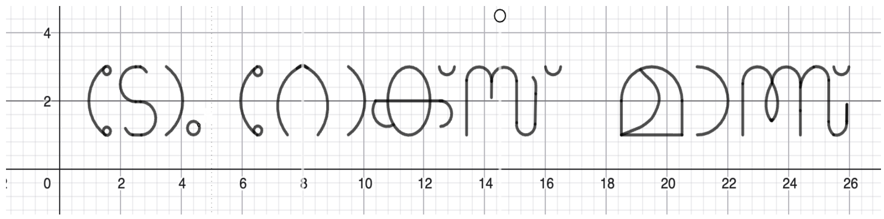
$K_1 = (12.5, 3)$

$L_1 = (12.7, 2.8)$

$M_1 = (13, 3)$

$d_1: \text{CircumcircularArc}(K_1, L_1, M_1)$
$= 0.8$

After this point, the process gets quite repetitive until I finally complete the tedious yet captivating task of graphing a phrase in the Malayalam script onto GeoGebra using some of the simplest tools: splines, arcs and reflections all amalgamating into one Malayalam masterpiece.



So, can you actually graph a language? After spending about 72 hours staring at grids and tweaking splines, I'd say the answer is a "yes," but with a bit of a catch. Using GeoGebra to turn a phrase like “ടോം റോക്സ് മാത്സ്” which translates to **“Tom Rocks Maths”** into a collection of arcs and reflections showed me that there's this hidden geometric logic to the Malayalam script that most of us just take for granted. We see a letter; maths sees a series of coordinates and constraints.

Writing this out also made me think back to the Knot Theory I mentioned earlier. In mathematics, a knot is basically a closed loop that can't be untangled without a pair of scissors. When you look at the overlapping loops and "intersections" in characters like “ക്”, the script starts to look like a 2D version of those complex topological maps. It's not just about drawing lines; it's about how those lines weave together to create meaning.

In the end, trying to fit a fluid, hand-carved history into a rigid graphing system was a lot harder than I expected. It's a delicate balance between mathematical simplicity and the actual "flow" of the handwriting. It's definitely a project that requires a lot of patience. **It's easy to get tied up in the details, but you eventually just have to work through the knots!**