

Art: A Math Motivated by Beauty

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As most science majors are accustomed, when you're a science major, you tend to not focus on much else outside of the sciences. That is to say, you don't feel the need to be an expert on any other subject area. For example, most math majors are quite comfortable expressing their lack of desire or need to use proper grammar or have above average writing skills. Biology majors don't care to know much about western art, and along the same lines, English majors could do without math past your basic algebra course, and so on. These are generalities, of course, so they do not and will not apply to everyone, but nonetheless, they hold some truth for some. Personally, I wanted to challenge this, slightly. I think it's a good thing to be balanced and well-rounded, to keep interests in different branches, to expand your horizons and interests, if nothing else just to boost your general knowledge and conversational/relatable skills. So, as a math major, I took an art class and decided to pursue the minor. In doing this, I've expanded the way I think so much. I was able to see connections between these two fields that I wouldn't have otherwise. Seeing a small glimpse of these connections is what propelled me to further explore what other connections I could find.

Upon simple reflection, a certain connection between art and math can be seen in many ways. There are many artists, like M. C. Escher, Durer, and Da Vinci, who are very intentional about including math in their art. M.C. Escher's tessellations, for example, require careful calculations, combinations and rotations to come to life¹. Durer went through a series of

¹ Schattschneider, Doris. 1987. "The Polya-escher Connection". *Mathematics Magazine* 60 (5). Mathematical Association of America: 293–98. doi:10.2307/2690411.

calculations involving depth and perspective to ensure his drawings and paintings were accurate to life and looked so on the two-dimensional canvas². Da Vinci has a whole book and movie dedicated to the work he put into mathematically deciphering a formula that would allow him to draw the perfect man³.

Not only is math used to create these specific examples in art, but it's used in the general drawing process as well. As Wei Xu of the Art Institute of California shows us, using math is essential to creating accurate representations when drawing. Two methods he discusses that help artists create these accurate renderings are projection and the grid method. With projection, you project whatever three-dimensional object you are trying to draw onto a two-dimensional surface. With the grid method, you create an imaginary grid around your object, then grid your canvas, and match each square of your grid to where it should be in real life-similar to building a puzzle.

Taking into consideration all these different applications of math in art, I decided to explore some of the western world's 'favorite' or more popular paintings to see what, if any, mathematical connections they had, and if these could be what makes them so aesthetically pleasing. The twenty-six paintings I chose were: *The Mona Lisa*, *The Scream*, *The Last Supper*, *The Starry Night*, *The Persistence of Memory*, *Guernica*, *Bal du moulin de la Galette*, *The Birth of Venus*, *The Night Watch*, *The Kiss*, *The Last Judgement*, *The School of Athens*, *Arnolfini Portrait*, *Landscape w/the Fall of Icarus*, *The Calling of St. Matthew*, *Venus and Adonis*, *Self Portrait as St Paul*, *Las Meninas*, *Les Demoiselles d'Avignon*, *Impression*, *Sunrise*, *Girl with a*

² Silver, Daniel S. "Slicing a Cone for Art and Science." *American Scientist*, September/October 2012, 408-15.

³ Shapiro, Alan E. "Math and the Mona Lisa: The Art and Science of Leonardo da Vinci." *Physics Today* no. 7 (2005): 63. *Academic OneFile*, EBSCOhost (accessed May 3, 2016)

Pearl Earring, Number 5, 1948, The Bathers, Madonna, Dance at Bougival, and Tower of Babel.

To these, I applied three methods and analyzed the results to decide if any connections could be drawn.

My first method of analysis was a simple exploration of the positive to negative space ratio found in each of the paintings. Positive space refers to the space the object of focus for a painting or drawing takes up on the canvas, and negative space refers to the rest of the space on the canvas, in other words, the background space. In the image below, (a) and (c) illustrate this relationship. In (a) the space taken up by the black chair is our positive space, the white background makes up the negative space. Image (c) is a negative or inverse of image (a), so here, the chair becomes white, still representing our positive space, and the background is now black, still making up the negative space⁴.



(a) Original Chair



(b) Simple Shapes



(c) Negative Spaces

⁴ Xu, Wei. "Learning Drawing with Math: A Scientific Approach." *International Journal of the Arts in Society*: 167-80. Web. 20 Apr. 2016.

In general, the steps were first to use the ImageJ “Rectangular selection tool” to select the whole image to get a total area. Then, for each image, I made the following decisions and traces to get a positive (or negative) space area, which then allowed me to calculate the positive space percentage.

- 1- Mona Lisa: For da Vinci’s Mona Lisa, I considered the woman featured in the painting as the positive space, tracing from her left shoulder (our right) up to and around her hair, down her right (our left) shoulder to the bottom of the painting, then across to the bottom right corner, up her arm and back to her left shoulder. This gave me a total positive area of 7,529,894 pixels, out of a total area of 11,687,536 pixels, equating to a 64.4 percentage of positive space.
- 2- The Scream: For Edvard Munch’s The Scream, I took the person holding their head, the “screamer,” as the positive space, and everything else as negative space. I traced him starting from the bottom left corner, up the arm, around the head, back down the shoulder, to the bottom of the painting and then followed the bottom border back to my initial point. This trace gave me a positive area of 122,140 pixels, which, out of a total area of 1,136,980 pixels, gave me a 10.7 percentage for positive space.
- 3- The Last Supper: For this painting of da Vinci’s, I traced the strip of disciples and Jesus, beginning at the bottom right corner of Simon’s robe (the right-most disciple), coming up the edge of the painting along his shoulder, up and around his head, down his shoulder, to his hand, where I came back up along Jude’s robe, up and around his beard and head, to his shoulder, up Matthew’s chin and face, around his head, down his shoulder, until his arm meets Philip’s robe, up it, around his head, to James the Greater’s head, to Thomas’ head, down his face, around his hand, down to James the Greater’s arm and hand, to

Jesus' shoulder, up and around his head and hair, down his shoulder and arm, up John's arm, around his head to Peter's, then onto Judas', back to Peter's shoulder, over James the Minor's arm, to Andrew's beard, up it and over his head to James the Minor's head, to Bartholomew's head, down his neck, down the edge of the painting to the corner of Bartholomew's robe, across his hand, to Andrew's elbow, continuing across, following the line created by their robes and hands, all the way back to my beginning point⁵. This trace gave me a total positive area of 179,291 pixels, out of a total area of 662,830 pixels, for a positive space percentage of 27.

- 4- The Starry Night: This particular painting of van Gogh's gave me a hard time, because the main focus of the painting, the stars and the sky, would technically be considered background, so negative space, but it didn't make sense to me to do this, so I chose my positive space to be the sky and the tree or smoke like image in the foreground, leaving the mountains and village as negative space. I began tracing at the bottom left corner of the dark image at the front, up it to the point it meets with the sky (right above the dark blue mountains in the background), then left to the edge of the painting, straight up the edge, turning right to follow the top edge, then back down the left edge of the painting, until the dark mountains, where I followed the curves of the tops of the mountains back to the black tree-bush, down it to the bottom edge of the painting, and back to my beginning point. This trace produced a positive space of 839,559 pixels, out of a total area of 1,140,000 pixels, resulting in a 73.65 positive space percent.
- 5- The Persistence of Memory: For this painting, I considered the objects in the painting the positive space: "the masturbator" (the floating head like figure), the clock on its face, the

⁵ Debbie. "Dom Donald's Blog." *Last Supper*. 24 Aug. 2013. Web. 20 Feb. 2016.

clock hanging from the branch, the clock dripping off the edge of the box, and the orange pocket watch off towards the bottom left of the painting. Tracing these gave me a total positive area of 117,497 pixels, which, out of 785,408 pixels total area, results in a 15 percent of positive space.

- 6- Guernica: Picasso's Guernica was tricky, because it's a collection of weird objects, all in a tone of gray, and overlapping each other, so deciphering what was foreground and what was background was difficult. I ended up choosing to do three separate traces. For the first block, I went around the outer brim of all the objects, starting on the bottom left corner, with the big toe looking thing, moving right, following the curves of the toes, then up the foot and around the ankle, left to the gray triangular shape, up its edge, following the box shape, up and down the teeth, up and back down the white semi-lunar shape, up the arm and around the fingers, down the arm, following the curves of the head, around the chin and down the neck, back up the other arm, around the fingers again, down the arm and around the white circle, down the other triangle side, up the white hand thing, to the hair like thing from the head, to the head, around the face, back down the neck, down to the foot, around the toes, back up and towards the right to other fingers, down light gray, triangular/knee-like thing, back to the beginning toe. For the second block, I started with the white blob face on the upper middle right of the painting, starting at the neck, following it down to the chin, up the face, to the light gray arm like thing that comes out around eye level, moved left down the arm, around the horse's hair, down to the fingers of the arm on the bottom edge of the floor, around it and up the newspaper foot, around to the crazy head, following it from below, to the light gray arm thing, around it, back to the upper/face part of the head, up the horse tail, around the newspaper shape, back up the

horse's neck, around its mouth, nose, head, and ears, up and around the candle light, following the upper curve of the arm, back to the starting point. The final block I started at the upper left of the painting, at the bull's tail, down it, continuing down its leg, around its hoof-like things and around the white head and triangle, up the finger-like things, across the bottom of the bull's belly, back down its other foot, back up the other side, up around its white neck and head, across its back, and back up the tail to the starting point. Adding these three blocks gave me a total positive area of 1,728,085 pixels out of a total area of 3,840,000 pixels, resulting in a 45 percent positive space.

- 7- Bal du moulin de la Galette: Renoir's painting also forced me to think creatively when choosing what was going to be positive space and what I would leave as negative space. I chose to have the people gathered on the bottom left corner of the painting, around the table and bench, be the positive space. I began my trace with the brim of the yellow hat the guys sitting all the way to the right edge of the painting is wearing, following the curve up and then slightly down to the head/hat of the guy next to him, up and around his head, down the side of his face and arm, to the shoulder of the guy whose back is to the viewer, up the side of his back and head, around and back down, around his hand to the woman's hand, up the woman in the dark dress' arm, up and around her face and hat, down her back, all the way down to where the bench covers the dress at the bottom edge of the painting, across to the other girl's pink dress, following the bottom edge of the painting, then back up the rightmost edge of the painting back to the starting point. This resulted in a 309,133 pixel positive area, out of a 1,066,220 pixel total area, giving me a 29 positive space percentage.

- 8- The Birth of Venus: For the Birth of Venus, I chose the people and shell to be the positive space, so I traced the woman all the way to the right of the painting, then Venus and her shell, then the angel and woman all the way to the left, including each of their respective wings, robes, and hair. Summing the three gave me a total positive area of 423,320 pixels, out of a total area of 903,600, resulting in a 46.85 percent positive space.
- 9- The Night Watch: For this painting, I traced the three figures that are emphasized by light, the man in the light yellow/champagne colored clothing in the center-right of the painting, the man beside him dressed in black with a red sash, and the little angel figure in the center left of the painting. Tracing the three of them gave me a positive area of 192,186 pixels. That, out of a total area of 1,023,660 pixels, yields an 18.77 percent positive space.
- 10- The Kiss: Gustav Klimt's The Kiss was relatively easy and straight forward. I traced the two figures enveloped in gold, following the brim of the gold, around her feet, leaving out the green-purple grass at the bottom. This trace yielded a positive area of 17,723,303 pixels, which, out of a total area of 54,110,592 pixels, results in a 32.75 positive space percentage.
- 11- The Last Judgement: Michelangelo's was quite tedious, as the only technical background space is the sky and potentially the water and tiny piece of land seen at the bottom. So, for this painting, I did a backwards trace; that is, I traced the few parts of sky that can be seen behind and around the multitude of angels in the painting, and subtracted that number from the total area to get total positive area. The negative space area was 75,106 pixels, subtracted from a total area of 457,368 pixels resulted in a positive area of 382,262 pixels, which gave an 83.58 percentage of positive space.

- 12- School of Athens: For Raphael's School of Athens, it was difficult to decide what was positive and what was negative space. After several different traces, I decided the best option was to consider the entire scene "on stage" as the positive space, so I began my trace at the bottom right corner of the platform/elevation (where the blue column elaborated in white and gold meets the square tiled floor), moved up the column and around the arch, following its curve all the way back down to the other column, following the corners formed back to the floor, then back to the starting point. This trace generated a positive space area of 2,457,273 pixels and, out of a total area of 11,234,484 pixels, a positive space percent of 22.
- 13- Arnolfini Portrait: Van Eyck's painting was one of the easier ones- I just traced the two people as the positive space, starting with the woman on the right, following the outline of her robe, then head piece, down her arm to his, up his arm to his face and hat, following his robe down the left side of his body, then across to and around his feet, back up his robe to their arms, across back to her robe, following it back down to and around the floor, back to the starting point. This trace produced a positive space area of 5,771,424 pixels out of a total area of 12,893,312 pixels, resulting in 44.76 percent positive space.
- 14- Landscape with the Fall of Icarus: For this painting, I only considered the man, the plow, and the horse seen in the foreground as our positive space, which yielded a positive area of 138,339 pixels out of a total area of 2,530,008 pixels, meaning a 5.5 percent positive area.
- 15- The Calling of St. Matthew: For this painting, I traced the outlines of the people portrayed, starting with the hat of the man standing under the incoming beam of light,

following down his face to the old man's head, up and around it to the first man's arm, following it down to the guy seating with his back to the viewer's hat, up and around it the shoulder/arm of the guy dressed in yellow, up his face and around his hat and feather, back down and around his puffy sleeve to the bearded guy's beard, up his face, around his hat to the other guy's head, around it, and around his coat/back to the last guy's back, down his back and following the curve of his leg down then back up to the table, his arm, the other guy's hand, to the back edge of the table, following it to the white sleeve of the guy whose back is to us, down it to his left leg, down it then back up it, crossing around his butt to the other leg, down it then back up it, up his right sleeve to his face, back up to the first guy's hand, down it to the old man's hand, down his profile, robe, leg, back up it and back down it, around the lifted heel back up the leg, then up the robe, around the first guy's neck, back to our starting point. This entire trace produced a positive space area of 213,938 pixels, out of 611,235 pixels total area, resulting in a 35 percent positive space.

16- Venus and Adonis: For Venus and Adonis, I traced Venus, Adonis, and the cherub/cupid who's pulling at Adonis' leg. I began with Venus' left foot, all the way to the bottom right corner of the canvas, up her leg, following the curves of her body up and around her head, down to her arm, across to Adonis, up his shoulder and around his head, down his hair, up his arm, around his hand, then back down his arm, down his back, following the curves of his body and fabric down to his leg, around his foot, back up his leg, across the fabric, down his other leg, back up to Cupid's arm, across it and down his belly and leg, around his foot and back up the side of his leg, following the curve of his butt, back, and wings, around his head back down to his arm, continuing back up Adonis' leg, to Venus' arm, down to Adonis' arm, around his hand, up his arm to Venus' arm, back to her body,

following the curves of her stomach, hip, thigh, and leg down to her foot, around it and up the side of her leg where the other leg's knee comes in, down that leg, back to our starting point at the foot. This trace gave me a positive space area of 57317 pixels out of a total area of 199794 pixels, resulting in a 29 positive space percentage.

17- Self-portrait as St. Paul: For this one, I started all the way in the bottom left corner, going up his back, across his back/shoulder to his head, around it, down the side of his face, down to the book, around it to the bottom of the canvas, across to the starting corner. This trace yielded a positive area of 41236 pixels, and out of a total area of 74400, the positive space percentage was 55.

18- Las Meninas: For this painting, I began with the little girl all the way to the right, going up her hair, around her head, down to and across her arm, up the next girl's shoulder, around her head, down her neck to her shoulder, across to the next girl's dress, up her back, around her head, down her face, shoulder, arm, hand and dress to the next girl's arm, up it, around her head, down her shoulder and arm to the next girl's hand, up to and around her head to Velazquez's arm, up it and around his head, down his shoulder, down the line created between the edge of the painting and his and the girl's robes and dress, around the fabric of the girl's dress, following to the next girl's dress, to the next, to the puppy, down his leg, following the contour of his body on the floor to the second to last girl's dress, up the edge of the dress, across to the last girl's leg, down it to her foot and around it to the right edge of the canvas, and up to our starting point. This resulted in a positive space area of 3450508 pixels out of total area of 13590720 pixels, giving us a 25 percent of positive space.

19- Les Demoiselles d'Avignon: In this cubist artwork, I considered the pink women the positive space, so I traced strictly around the pink bodies or if there was fabric directly on them then around that. I began my trace with the elbow in the middle right of the canvas, going up the arm to the above woman's hip/butt, following the curves/lines up to the head, around it, down it then back up the amount of pink arm that can be seen, around and down it, following the pink, not red, down to the lower woman's head, around it and down the pink arm, down the pink leg, following the curve created by the watermelon and white cloth to the middle woman's leg, up it and around the white fabric on her mid-section, continuing to follow the pink curves/lines of the body up to the folded arm, around it down to the other folded arm, down to the next girl's shoulder, up it and around her head to her folded arm, up and around it to the last girl's head, up the hand and back down, down the back of her head, covered arm and covered leg (slightly brighter pink, but still not the red), around the foot, up the leg, following the body all the way back up to the head, where it meets the other girl's arm, down that arm all the way to that girl's second leg, following the diagonal up to where it meets the white fabric, down to the middle girl's pink leg, following the same curve we followed earlier (the one created by the fabric and watermelon) back to the first girl's leg, down, around and back up it, around the butt, and back up the other leg to the elbow where we began. This trace yielded an area of 10213334 pixels, which, out of a total area of 20172288 pixels, results in a 47 percent positive space percentage.

20- Impression, Sunrise: For this one, I considered only the little boat in the middle to be the positive space, so I traced it and yielded a 12604 pixel positive space area, which out of a total area of 1981520 pixels results in less than a 1 percent of positive space.

21- Girl with a Pearl Earring: Here, it's evident the girl is the positive space and the black background the negative space, so I traced around the girl, starting at the bottom mid-left of her clothes, following the curves of the fabric up to the neck, continuing around the face and head wear, down the fabric of the yellow headpiece, across it to the back of her fabric, back down to the bottom of the canvas, and then following the bottom border of the canvas back to the starting point. This trace gave me a positive space area of 7986674 pixels, and out of a total area of 19447872, a 41 percent of positive space.

22- Number 5, 1948: This is the only painting that I was unable to do a trace for. Due to the nature of the painting, you can choose to see it as 100 percent positive space or 100 percent negative space. I chose to see it as 100 percent positive space, as the whole canvas is filled with paint splatter, the subject of the painting.

23- The Bathers: For *The Bathers*, I considered all of the women in the foreground the positive space, beginning my trace going up the back of the body all the way to the right edge of the canvas, around her head, down the shoulder/arm, up the back girl's leg, around her body, down her arm to the next girl's back, up it and around her head, down her shoulder and arm to the next girl's back, up it and around her head, down her arm to the back of the middle-right girl's head, around it and down her arms, across to the slightly back girl's hand, up it, around the back arm, up to the further back girl's head, around it, down her arm/shoulder, up and around the back of the head of the next girl, to the last girl's arm, up her arm to her head, around it and down her back, all the way down to her foot, around it, back up her leg, across her other leg to the next girl's back, down it, around her butt, foot, and hand to the slightly further back girl's hand, up the thigh and body to her other arm, down it to her hand, meeting the line we drew here earlier, back to

the middle-right girl's hands, around her feet/legs and butt, to the next girl's leg, down it and around her feet, back around to the first girl's butt and back up her back to our starting point. This trace yields a positive space area of 8056440 pixels, out of a total area of 33733440 pixels, giving us a 24 percent positive space.

24- Madonna: For this piece, I chose the woman to be the positive space, tracing up from her bottom right corner, around the curve of her body to her hair, around her head and hat, back down her body and back across to the starting point. This gave me a positive space area of 3072574 pixels, out of a total area of 13020672 pixels, resulting in a 24 percent positive space.

25- Dance at Bougival: In this image, the woman and man depicted in the center dancing are the positive space, so I traced them, beginning at the bottom right with the man's pant leg, going up his leg, around his suit jacket, up his arm, around their hands, to hers, up and around his hat to hers, around hers and down it to her dress, down her back, around his arm/hand, continuing down her dress, around the skirt, back to his pant leg, down it, around his shoe, back up that pant leg to the heel of the other shoe, back to our starting point. This trace yielded 614925 pixels of positive space are, out of a total area of 1184040 pixels gives us 52 percent positive space.

26- Tower of Babel: For this painting, I considered the tower itself to be the positive space, so I traced all around it, starting at the bottom right corner, moving up to the top, across, then back down the left side of the tower, across the bottom front, staying on the edge of the tower, following it back to the starting point. This trace gave me a positive space area of 392876 pixels, which out of a total area of 1050088 pixels, gives us 37 percent positive space.

The results for this method were an average positive space percentage of 38, negative space percentage of 62. This average, however, is not an accurate representation of the positive space percentages for each painting, because, as can be seen in the graph below, only four out of the twenty-six paintings fall within the plus 5/minus 5 range of 38 percent positive space.

Painting	Positive Area	Total Area	% Positive	% Negative
Mona Lisa	7529894	11687536	64.43	35.57
The Scream	122140	1136980	10.74	89.26
The Last Supper	179291	662830	27.05	72.95
The Starry Night	839559	1140000	73.65	26.35
The Persistence of Memory	117497	785408	14.96	85.04
Guernica	1728085	3840000	45.00	55.00
Bal du moulin de la Galette	309133	1066220	28.99	71.01
The Birth of Venus	423320	903600	46.85	53.15
The Night Watch	192186	1023660	18.77	81.23
The Kiss	17723303	54110592	32.75	67.25
The Last Judgement	382262	457368	83.58	16.42
The School of Athens	2457273	11234484	21.87	78.13
Arnolfini Portrait	5771424	12893312	44.76	55.24
Landscape w/the Fall of Icarus	138339	2530008	5.47	94.53
The Calling of St. Matthew	213938	611235	35.00	65.00
Venus and Adonis	57317	199794	28.69	71.31
Self Portrait as St Paul	41236	74400	55.42	44.58
Las Meninas	3450508	13590720	25.39	74.61
Les Demoiselles d'Avignon	9490349	20172288	47.05	52.95
Impression, Sunrise	12604	1981520	0.64	99.36
Girl with a Pearl Earring	7986674	19447872	41.07	58.93
Number 5, 1948		98112	100.00	0.00
The Bathers	8004736	33733440	23.73	76.27
Madonna	3072574	13020672	23.60	76.40
Dance at Bougival	614925	1184040	51.93	48.07
Tower of Babel	392876	1050088	37.41	62.59
Average	2850058	8024468	38	62

The second method I used was to find the center of mass for each painting. Center of mass refers to a point used to describe the forces or torques acting on an object. In art, finding

the center of mass is usually synonymous with finding the point on the canvas your eye is most drawn to, or keeps getting drawn back to. There are various ways of calculating center of mass, but for a two-dimensional discrete mass, it is calculated using three points, each requiring a weight value. Using ImageJ, I put each image through RGB decomposition- that is to say, I broke down each image into three separate ones, one representing all the red values of the image, another representing all the green, the last all the blue. Once the images were broken down, ImageJ was able to produce a center of mass point and a mean value for each red, green, and blue decomposed image. Using these three points and their associated mean values, I used the following formula to calculate the center of mass for each painting image as a whole⁶.

$$\bar{x} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3} \quad \bar{y} = \frac{m_1y_1 + m_2y_2 + m_3y_3}{m_1 + m_2 + m_3}$$

Listed below are the results- the red, green, and blue x and y values for each center of mass point, the mean value associated to each point, and the last two columns are the x and y values for the center of mass point for the image as a whole.

Painting	Red-X	Red-Y	Red-Mean	Green-X	Green-Y	Green-Mean	Blue-X	Blue-Y	Blue-Mean	Center X	Center Y
Mona Lisa	1352.87	1556.35	82.32	1352.36	1364.84	57.43	1307.06	1523.38	24.64	1345.82	1484.50
The Scream	429.6	544.164	113.58	454.277	583.798	78.773	452.057	609.562	64.593	442.81	572.76
The Last Supper	617.386	355.925	108.773	623.499	357.687	89.964	626.86	351.55	78.92	622.06	355.25
The Starry Night	644.56	420.381	76.433	638.622	419.601	92.506	625.779	410.641	110.081	635.18	416.28
The Persistence of Memory	444.106	298.561	92.596	457.971	245.713	84.377	450.891	230.557	77.63	450.77	260.31
Guernica	1532.78	615.389	123.807	1532.77	615.39	123.806	1532.721	615.368	123.802	1532.76	615.38
Bal du moulin de la Galette	564.046	412.108	55.04	558.132	409.623	60.31	539.99	440.056	51.76	554.46	419.87
The Birth of Venus	559.914	379.654	94.46	542.742	380.298	83.98	530.144	377.946	63.43	546.14	379.43
The Night Watch	610.734	553.367	26.98	608.718	543.703	22.957	605.187	538.451	16.604	608.65	546.31
The Kiss	3648.709	3742.7	148.568	3592.739	3840.814	132.345	3482.779	3938.812	76.883	3592.35	3821.13
The Last Judgement	323.27	388.875	143.417	321.693	399.817	110.65	320.415	396.481	91.048	322.01	394.39
The School of Athens	1949.505	1451.024	147.054	1956.238	1442.739	130.737	1968.141	1445.474	103.127	1956.86	1446.68
Arnolfini Portrait	1577.384	2022.441	51.996	1563.049	2112.687	43.729	1430.9	1972.206	28.969	1538.33	2042.42
Landscape w/the Fall of Icarus	1078.005	551.499	109.329	1081.516	523.425	106.72	1094.942	458.933	78.494	1083.79	516.66
The Calling of St. Matthew	476.896	305.983	49.068	475.075	305.299	30.086	438.978	354.692	9.994	472.03	311.21
Venus and Adonis	214.197	194.465	84.881	214.754	191.882	72.767	201.969	176.921	41.878	211.83	189.84
Self Portrait as St Paul	104.944	117.534	31.073	100.498	114.275	26.17	100.962	119.12	22.013	102.37	116.90
Las Meninas	1623.705	2328.215	66.909	1653.007	2267.257	53.17	1675.121	2219.427	40.088	1646.30	2280.75
Les Demeisilles d'Avignon	2264.366	2354.448	173.288	2345.548	2309.819	139.754	2360.044	2303.479	131.603	2318.20	2325.34
Impression, Sunrise	798.006	593.065	133.968	802.013	609.862	144.701	805.511	613.008	137.779	801.88	605.50
Girl with a Pearl Earring	2325.241	2700.323	50.915	2336.781	2620.01	44.218	2221.145	2407.173	47.327	2294.24	2578.01
Number 5, 1948	109.707	220.842	94.637	109.86	221.798	80.113	110.081	220.883	67.635	109.86	221.17
The Bathers	316.755	269.588	129.407	3163.667	2544.279	119.1	3143.643	2359.711	106.909	3161.99	2539.46
Madonna	1554.773	2100.209	107.156	1551.635	2204.839	86.387	1553.147	2215.463	77.913	1553.31	2166.59
Dance at Bougival	375.219	838.681	157.785	369.777	848.123	142.878	357.907	854.035	121.839	368.39	846.30
Tower of Babel	570.69	380.97	105.072	577.055	373.569	94.335	587.631	332.77	69.091	577.29	365.97
Average	1113	1082	98	1115	1071	87	1097	1057	72	1110	1070

Stanbrough, J. L. "Center of Mass in Two Dimensions." *Center of Mass in 2 Dimensions*. 01 Feb. 2010. Web. 05 Mar. 2016.

The average center of mass point reflects a point almost perfectly at the center of the canvas, which is a close approximation for most of the paintings, not by numerical value because each painting was a different size, but by placement. After each image was divided into thirds, every single center of mass point turned out to be in the central block of the 9 x 9 grid. This implies that, on average, the point your eye keeps coming back to is in the center, which is interesting because as a general rule, you don't want the viewer to get stuck in the center of your canvas, but rather you want to keep their eyes moving around the canvas. Maybe this is why that rule is in place, because it's already natural for the viewer to want to get stuck in the center, so you don't want to add focus dead center.

This brings me to my final method-the rule of thirds. The rule of thirds is straight-forward: you divide your canvas into thirds vertically and horizontally, resulting in a 9 x 9 grid. As mentioned earlier, you want to keep the viewer's eyes moving around the canvas. To do this, you want to keep the focus of your drawing or painting either on one third or on two thirds of the canvas, never in the center (except in the case of a portrait) so as to avoid getting the viewer stuck on the center of the painting or drawing.

In general, most of the paintings I examined in this research employed this rule. Even some of the portrait paintings stuck to the rule in one direction. For example, The Mona Lisa is in the central vertical third, but when looking at the horizontal thirds breakdown, her head takes up one third, and her torso the remaining two-thirds. Similar thing can be observed with The Scream, where the screamer takes up the middle vertical third, but only the bottom horizontal two-thirds.

The three methods I used, the rule of thirds, positive to negative space ratios/percentages, and center of mass point, all seem to have a connection in “good” art. However, the average results from the twenty-six paintings surveyed do not imply or represent their usage well. To get a closer approximation, one must look at each individual painting. Maybe that’s the little extra that makes art so hard to quantify- that even though one can find math used in every artwork, it’s used in different ways, unique to each piece. And while the use of math unifies them, this unique quality makes it so that you can’t just apply a general math rule to sum it up, you have to appreciate each piece individually, for what it represents and means and evokes in you.

Bibliography

"30 Analyze▷." ImageJ User Guide. October 02, 2012. Accessed March 03, 2016.

<https://imagej.nih.gov/ij/docs/guide/146-30.html>.

Fisher, Elizabeth A., and John Rabung. 2009. “The Measure of Beauty and the Beauty of Measure”. *The Classical Journal* 104 (4). The Classical Association of the Middle West and South: 331–40.

<http://www.jstor.org/stable/27750256>.

Hart, George W.. 2006. “Mathematical Connections in Art”. *Math Horizons* 13 (3). Mathematical Association of America: 5–5. <http://www.jstor.org/stable/25678595>.

Schattschneider, Doris. 1987. “The Polya-escher Connection”. *Mathematics Magazine* 60 (5).

Mathematical Association of America: 293–98. doi:10.2307/2690411.

Silver, Daniel S. "Slicing a Cone for Art and Science." *American Scientist*, September/October 2012, 408-15.

Shapiro, Alan E. "Math and the Mona Lisa: The Art and Science of Leonardo da Vinci." *Physics Today* no. 7 (2005): 63. *Academic OneFile*, EBSCOhost (accessed May 3, 2016).

Xu, Wei. "Learning Drawing with Math: A Scientific Approach." *International Journal of the Arts in Society*: 167-80. Web. 20 Apr. 2016.

Debbie. "Dom Donald's Blog." *Last Supper*. 24 Aug. 2013. Web. 20 Feb. 2016.

Stanbrough, J. L. "Center of Mass in Two Dimensions." *Center of Mass in 2 Dimensions*. 01 Feb. 2010. Web. 05 Mar. 2016.

Reinking, Larry. "ImageJ Basics." ImageJ. June 2007. Accessed February 15, 2016.

<https://imagej.nih.gov/ij/docs/pdfs/ImageJ.pdf>.

Nave, Carl R. "Center of Mass." HyperPhysics. 2001. Accessed March 30, 2016.

<http://hyperphysics.phy-astr.gsu.edu/hbase/cm.html>.