

Course: MATH 400

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The Interaction Between Mathematics and Visual Arts

Traditionally, mathematics and visual arts seem like two distinct, unrelated disciplines.

Mathematics is commonly linked with precision and logic while visual art is driven by creativity and aesthetics. This dichotomous, segregated view impedes the knowledge of the strong, mutually reinforcing relationship between these two subjects.

On one hand, visual arts give assistance to mathematics in various ways. By providing innovative ideas through analogies, models, skills, structures, techniques, methods, and knowledge, visual artworks as a useful tool in mathematical education, especially at the elementary level. Integrating specific artworks into the mathematical learning process effectively develops young students' imagination, creativity, and problem-solving skills. (Tramonti et al., 2017) When being represented visually, mathematics concepts or ideas can be more accessible to a broader audience. The most prominent example of this practice is data visualization, the graphical representation of a massive dataset, or academically, the mapping between quantitative data and graphic elements, such as lines, points, and shape. As a sub-division of descriptive statistics, data visualization conventionally accentuates the effective understanding of numerical information. Nowadays, it has become a form of visual art, emphasizing the enhancement of experience and acquisition of knowledge and ultimately improving data's readability, usability, and functionality. (Li, 2018)

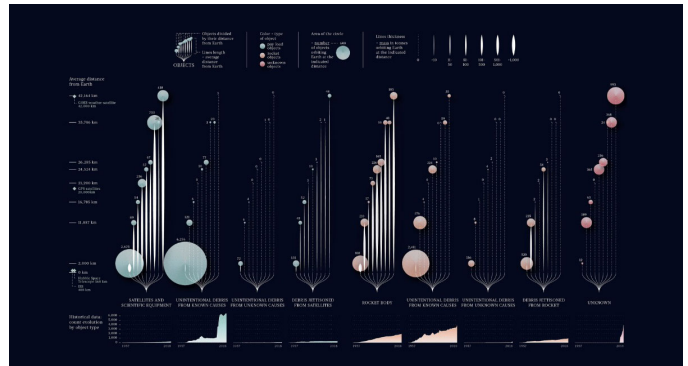
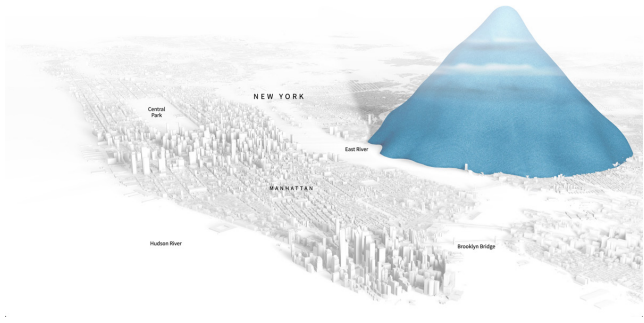


Figure 1. (Left) Pile of used plastic bottles & New York City (Scarr & Hernandez, 2019)

Figure 2. (Right) Space debris categorized by their average distance from Earth and the type of object (Fragapane, 2019)

On the other hand, mathematical concepts can be applied in visual art. This connection can be dated back to the 5th century BCE when Greek sculptor Polykeitos employed the golden ratio in his sculptures. Two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger one.

$$\frac{a + b}{a} = \frac{a}{b} \stackrel{\text{def}}{=} \varphi$$

Phi is a solution to the quadratic equation, with a value of:

$$\varphi = \frac{1 + \sqrt{5}}{2} = 1.618033 \dots$$

Over thousands of years, the 1:1.618... ratio, as well as the golden rectangle, whose side lengths are in the golden ratio, have become extremely important guides for artists and designers to make aesthetically satisfying and harmonious compositional decisions in drawings, paintings, sculptures and architecture.

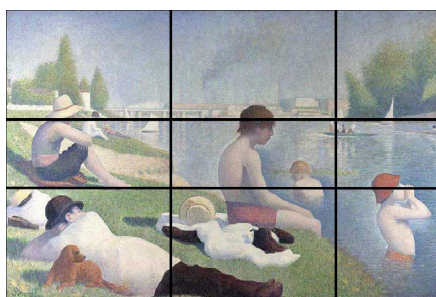


Figure 3. Georges Seurat, *Bathers at Asnières*, 1884

If we create rows and columns with 1:0.618:1 ratios and divide the painting above into nine sections, the rationality of golden ratio composition can be clearly explained. The horizon is precisely defined by the first horizontal line, therefore focus viewer's attention at the first glance. Moreover, Objects are almost evenly distributed into each rectangle, creating a pleasing visual balance and making the scene more dynamic.

In recent decades, an innovative form of visual art, the new media art, is emerging along with the acceleration of new media technology. Meanwhile, mathematics provides the conceptual scheme that technology builds upon. The new media art is characterized by connectivity and interactivity. It is an integration of art and science and involves interaction between viewers, environment and artwork. Computer graphics, animation, digital art, interactive art, video games, and 3D printing are all branches of new media art.

Turkish media artist Refik Anadol's most representative and current artwork, Quantum Memories, is an installation exhibited in the National Gallery of Victoria (NGV), Australia. Using artificial intelligence, quantum computation data, and machine learning algorithms, Anadol and his team created a so-called "data sculpture", a real-time, dynamic animation on an

LED screen. The following paragraphs will elaborate on the technical aspects of this stunning, interdisciplinary artwork.

1. **Data collection:** The preliminary dataset was consisted of over 200 million images of nature collected on the internet.
2. **Image classification:** A machine learning algorithm named ResNeXt was used for processing the preliminary dataset. ResNeXt begins with preprocessing, which is the elimination of unnecessary features and enhancement of essential features. In preprocessing, an image is converted into numbers so that the computer can understand. Then the location of the main objects is detected and features that are unique to specific classes are extracted. Once the features are compared with predefined classes, the algorithm moves to the final step, feature vectorization, and outputs a class or a probability that the image belongs to a class.
3. **Image clustering:** The high-dimensional, vectorized feature set was clustered and transformed into a three-dimensional data universe by a dimension reduction algorithm called UMAP (Uniform Manifold Approximation and Projection) which is based on Riemannian geometry and algebraic topology (McInnes, 2018).
4. **Image generation:** Using the preliminary image dataset as a training set, an additional set of artificial images was generated by GANs (Generative Adversarial Networks). GANs work with two mutually reinforcing neural networks, the generative network for generation and the discriminative network for evaluation. This double feedback loop ensures highly realistic images to be produced. At the same time, the new dataset is mapped to the latent

space in which previously unseen connections become visible. In other words, images with similar colors or objects are closer together.

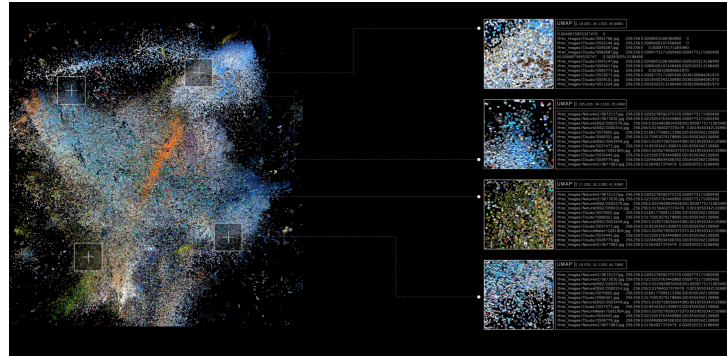


Figure 4. Clustered three-dimensional data universe (Anadol, 2020)

5. Visualization of quantum noise: Partnered with the Google Quantum AI team, Anadol “recycled” the seemingly useless quantum noise in publicly available quantum computing algorithms. The randomness triggered by quantum noise was turned into elegantly fluctuating motion effects.

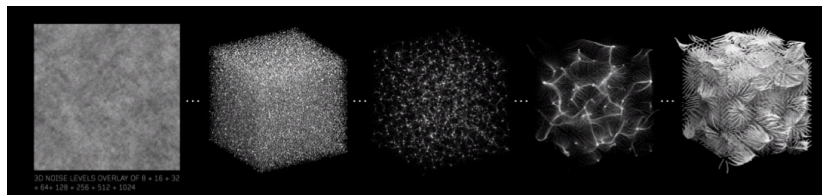


Figure 5. Quantum noise data sculpture (Anadol, 2020)



Figure 6. Quantum Memories, Public Art, 2020

In conclusion, the underlying beauty and elegance of mathematics can be revealed with the assistance of art, while supported by mathematical-related tools, artworks are empowered with technicality and elevated to a more rational level.

Reference

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