From Mosaic Tiles to Pixels: Reinterpretation of Selected Zeugma Mosaics

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This paper presents a digital art project that reinterprets the rich legacy of Anatolian mosaics using contemporary computational techniques. By converting mosaic tiles into digital pixels, the study creates a link between traditional craftsmanship and modern digital art. The project recreates selected mosaics digitally by assembling them from smaller mosaic images, using an algorithm in the Processing 4 environment. The algorithm divides the main image into a grid and selects smaller images based on color values to reconstruct the mosaic. Several significant Zeugma mosaics from Gaziantep, Türkiye, were successfully regenerated using a modified version of Daniel Shiffman's "Obama Mosaic" algorithm, tailored to fit the project's goals. This work emphasizes the potential of algorithmic art to bridge the gap between tradition and innovation, while showing how digital tools can preserve and transform traditional art forms in the modern age.

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Mozaiklerden Piksellere: Seçilmiş Zeugma Mozaiklerinin Yeniden Yorumlanması

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Bu çalışma, çağdaş hesaplamalı teknikler kullanarak Anadolu mozaiklerinin zengin mirasını yeniden yorumlayan bir dijital sanat projesidir. Mozaik karoları dijital piksellere dönüştürerek, geleneksel zanaatkarlık ile modern dijital sanat arasında bir bağ kurmaktadır. Proje, Processing 4 ortamında bir algoritma ile daha küçük mozaik görüntülerini bir araya getirerek, seçilmiş bazı mozaikleri dijital olarak yeniden oluşturmaktadır. Algoritma ana görüntüyü/ mozaiği karelere bölüp, bu mozaiği yeniden oluşturmak için her karenin renk değerlerine göre daha küçük görüntüleri seçip bu karelere yerleştirerek çalışmaktadır. Algoritma, Daniel Shiffman'ın "Obama Mozaik" algoritmasının değiştirilmiş bir versiyonudur. Projenin hedeflerine göre uyarlanmış bu algoritma ile Türkiye, Gaziantep'ten birkaç önemli Zeugma mozaiği, başarıyla yeniden oluşturulmuştur. Bu çalışma, dijital araçların modern çağda geleneksel sanat biçimlerini nasıl koruyabileceğini ve dönüştürebileceğini gösterirken, algoritmik sanatın gelenek ile yenilik arasındaki boşluğu kapatma potansiyelini de vurgulamaktadır.

Anahtar Kelimeler: Algoritmik Sanat, Mozaik Sanatı, Piksel Sanatı, Hesaplamalı Tasarım.

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1. INTRODUCTION

In order to experiment on how traditional mosaic creation can be reimagined through modern computational methods, this paper combines traditional mosaic artistry with contemporary computational techniques, focusing on the transformation of mosaic tiles into digital pixels. This is done by creating images from smaller units resembling pixels, which overlaps traditional mosaic creation. The study includes the use of algorithms to regenerate mosaic art, which situates it in the larger field of algorithmic art, which is the use of code and algorithms by artists to produce visual artworks. The digital regeneration of several Zeugma mosaics from Gaziantep, Türkiye, are focused on, in this study, to contribute the field of digital heritage by using digital tools to preserve and reinterpret cultural material.

1.1. Background

Various studies have looked closely at how traditional art forms might be digitally reinterpreted. Researchers have investigated how digital media, virtual reality, and computer-generated art have affected conventional art forms, emphasizing how these innovations have revolutionized artistic expression and audience participation (Kong et al., 2024). In example, research has investigated the possibilities and difficulties of integrating digital technologies with traditional Turkish arts like calligraphy and marbling, to protect cultural heritage (Kizilaslan & Kozlu, 2021). The authors showed examples of digitally produced artworks, not by algorithms but by graphic design softwares (**Figures 1, 2**).

Figure 1: Digital marbling work by İstanbul Ebru Evi (Kizilaslan & Kozlu, 2021).

Figure 2: Digital Calligraphy work by Erman Yordam (Kizilaslan & Kozlu, 2021).

Vilbrandt et al. (2011), worked on digitally interpreting Norwegian and Japanese traditional crafts by computationally modeling and fabricating them (**Figure 3**). Another study focused on the digital representation of Shan-Shui-Hua, a classic Chinese landscape painting, showing how Eastern aesthetic ideals can be recreated through Western digital approaches (Bolewski, 2008) (**Figure 4**).

Figure 3: From left to right: An outline of the original wood carving from the Lyngen region of Norway. A 3D model of it. A model made of wax. Final silver jewelry item (Vilbrandt et al., 2011).

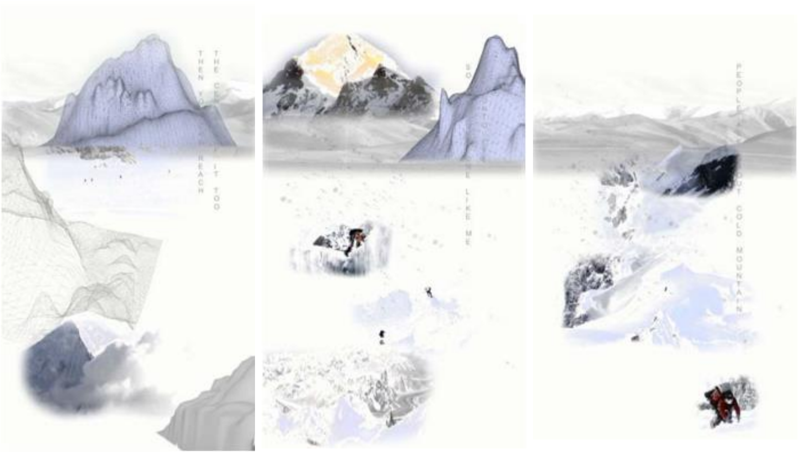

Figure 4: Images from Bolewski's work reinterpreting Shan-Shui-Hua (Bolewski, 2008).

These examples show the variety of ways that digital technology is reinterpreting classic artistic genres. The authors believe that immersive media forms present a chance to protect traditional artworks and make them more relevant to contemporary audiences. However, Holtzman (199,) argued that, with its distinctive features including interactivity and transient nature, the digital medium has been acknowledged as a venue for innovative creative expression with infinite reproduction possibility, but at the expense of temporality.

Studies have also been done focusing on digital reinterpretation of mosaics. Roman mosaics have been rebuilt using virtual restoration techniques (Monti & Maino, 2018) (**Figure 5**). Although there are certain restrictions in reproducing details and preserving consistency, artificial intelligence -specifically DALL-E2 - has demonstrated potential in reconstructing partial mosaics (Moral-Andr'es et al., 2024) (**Figure 6**).

Figure 5: Original mosaic on the left, virtual restoration on the right (Monti & Maino, 2018).

Figure 6: Original mosaic on the left, reproduction with AI model on the right (Moral-Andr'es et al., 2024)

Elber & Wolberg (2003) present a method for a digital mosaic forming system to convert digital photos into classic renderings that resemble mosaics (**Figure 7**).

Figure 7: Turning an image into a mosaic (Elber & Wolberg, 2003)

1.2. Digital Mosaic Generation Techniques

Puglisi & Battiato (2013) reviewed methods for producing high-quality digital mosaics automatically from raster images. According to authors, the process of generating a digital mosaic from a raster image can be viewed as a mathematical optimization problem. The goal is to take a rectangular region on a plane, a collection of tiles, and a set of specific rules, and find a set of positions where tiles can be placed. These tiles should be non-overlapping, cover as much area as possible, and follow the given constraints as closely as possible. To address different mosaic generation tasks, four methods are defined: Crystallization Mosaic, Ancient Mosaic, Photo-Mosaic and Puzzle Image Mosaic. The authors also gave visual examples from different researchers.

- Crystallization Mosaic: In this method, tiles are placed in such a way that each tile's color replicates the corresponding portion of the image. While the constraints on edge features are important, they can be relaxed to accommodate a feasible solution (**Figure 8**).
- Ancient Mosaic: The tiles are rectangles aligned based on a vector field influenced by the image's edges. The goal is to place the tiles without overlap, maximizing the area covered while ensuring the tile color matches the image (**Figure 9**).
- Photo-Mosaic: This approach uses a set of small rectangular images and places them on a regular grid. Each tile resembles the section of the image it covers, thus recreating the source image (**Figure 10**).
- Puzzle Image Mosaic: Similar to the Photo-Mosaic, but with an irregular grid and non-rectangular images. The task is to place these irregular tiles so they don't overlap and resemble the part of the image they are covering (**Figure 11**).

The first two techniques break the image into tiles with various colors, sizes, and orientations, while the latter two use pre-existing images to fill the mosaic grid. These last two techniques are referred to as multi-picture mosaics because they rely on fitting multiple small images to form a larger mosaic (Puglisi & Battiato, 2013).

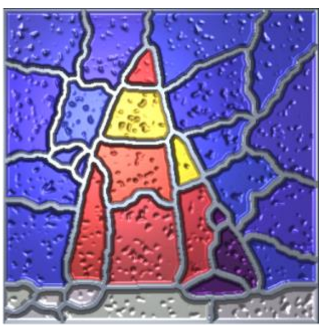

Figure 8: On the left, an example of crystallization mosaic (Mould, 2003).

Figure 9: On the right, an application of the ancient mosaic method (Puglisi & Battiato, 2013).

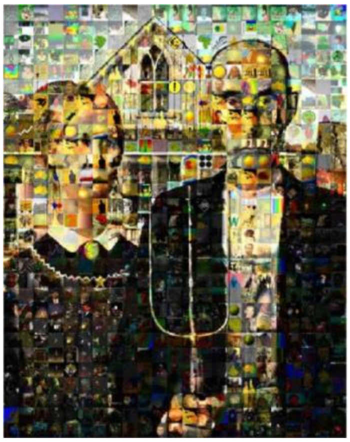

Figure 10: On the left, an example of photo mosaic, American Gothic (Finkelstein & Range, 1998).

Figure 11: On the right, an example of puzzle image mosaic made by Hausner in 2001 (Puglisi & Battiato, 2013).

1.3. Approach of This Study

This study uses the photo mosaic technique to generate digital mosaics from small images which works as tiles/pixels. For context, the study differs from the others with the approach of using mosaics as tiles to form bigger digital mosaics. Moreover, the focus is on generating several Zeugma mosaics by using Anatolian mosaics as tiles. In order to emphasize the shift from mosaic tiles to digital pixels, this study explores how the Zeugma mosaics might be reinterpreted and recreated in a digital format using contemporary computational techniques and algorithms.

1.4. The Zeugma Mosaics in Gaziantep, Türkiye

The ancient city of Zeugma is renowned for its Roman villas and the extensive mosaics that adorned their floors, covering over 1,000 square meters in area. The ancient city of Zeugma was strategically situated on the banks of the Euphrates River in what is now Gaziantep, Türkiye. It was founded in 300 BCE by Seleucus I Nicator, a general of Alexander the Great, later came under Roman control in the 1st century BCE and was renamed Zeugma. At its peak, Zeugma had a population of around 80.000, making it one of the largest cities of its time, comparable in size to Athens and larger than Pompeii and ancient London. Zeugma became a hub for artists, attracting the finest craftsmen of the time due to its strategic location at the crossroads of trade routes and a military garrison. The city's wealth and safety contributed to its cultural and artistic development, leading to the creation of mosaics, frescoes, and sculptures. The mosaic tradition at Zeugma evolved over time, beginning with the use of multicolored pebbles and later transitioning to the more refined tesserae technique, where stones were cut into cubes, rectangles, or triangles. This shift allowed for more detailed, picture-like mosaics, a hallmark of the Hellenistic and Roman periods (Zeugma, 2024).

2. METHODOLOGY

This study uses the photo mosaic technique and creative coding to form digital mosaics, in Processing4 IDE. Processing is an open-source program that runs locally on computers and includes a code editor to type code and a canvas that shows the visual outputs of the code (Processing, 2024). It is used mostly for generating visual art pieces. Daniel Shiffman's "Obama Mosaic" Processing4 code which was shared as open-source is taken as a base and manipulated for the purposes of this study (GitHub, 2024). His code uses smaller Barack Obama images as tiles to create selected Obama portraits (Figure 12).

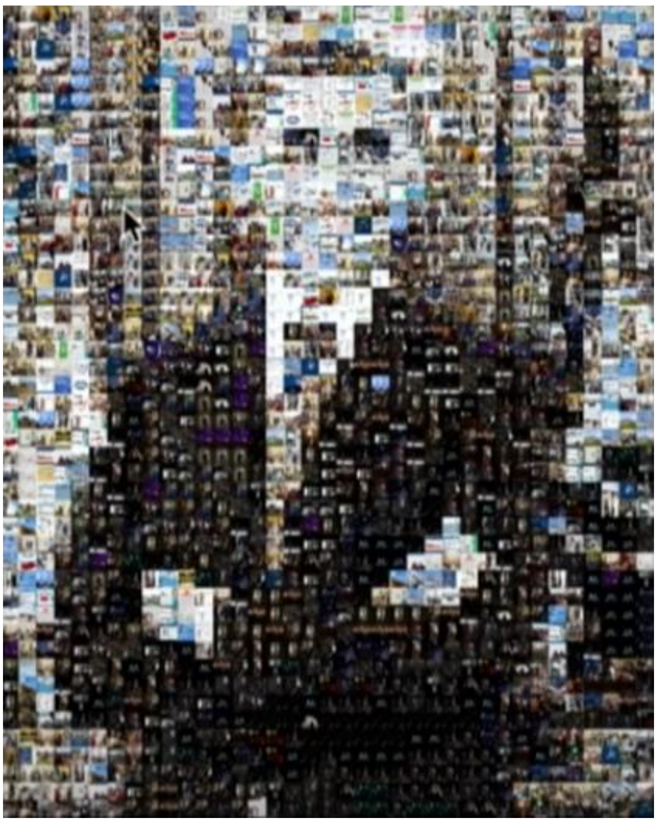

Figure 12: Obama Mosaic Work (Shiffman, 2022).

Pseudocode for Shiffman's "Obama Mosaic" algorithm and the flowchart are as follows (**Figure 13**):

- Initialization:
  Load an image (Obama's photo).
  Retrieve and store a list of files (image data) from a directory.
  Set up variables for processing images (brightness array, smaller images, etc.).
- Image Preprocessing:
  Iterate through the list of images:
  Load each image file.
  Shrink the image to a smaller size (16x16 pixels in example).
  Compute and store the average brightness of each shrunken image.
- Assigning Brightness-Closest Images:
  For each possible brightness value (0-255):
  Compare the brightness of each processed image with the target brightness.
  Find the image with the closest matching brightness.
  Store the best-matching image for each brightness value.
- Resizing Source Image:
  Resize the source image (Obama's image) into a smaller version, based on the predefined scale (16 pixels).
- Main Loop (Drawing):
  Iterate over the columns and rows of the smaller source image:
  For each pixel in the resized image, get its brightness.
  Use the brightness value to find the closest matching image from the array.
  Draw the matching image in place of the corresponding pixel.
- Displaying Results:
  Display the mosaic of images corresponding to the source image's brightness pattern.
- Stopping the Drawing:
  End the draw loop after one iteration.

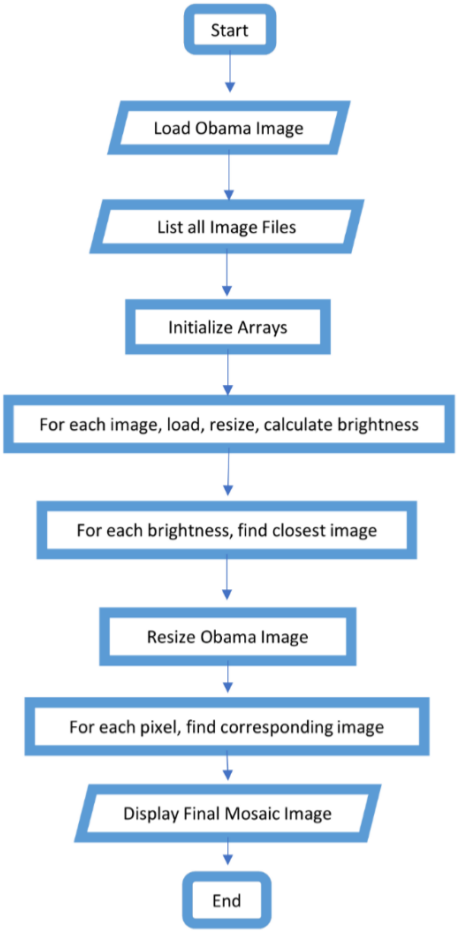

Figure 13: Flowchart of the Shiffman's "Obama Mosaic" algorithm (Author, 2024).

In this study, Daniel Shiffman's code is modified, focusing on color values (red, green, blue) instead of brightness. Therefore, instead of calculating the brightness of images, the code calculates the average red (or green or blue) channel value for each image to match images based on color similarity rather than brightness (**Figure 14**).

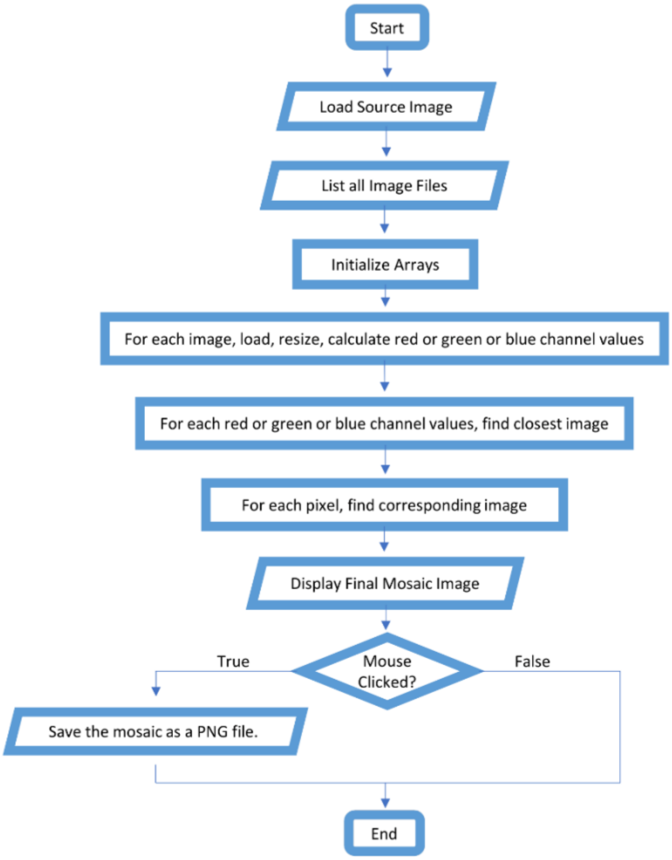

Figure 14: Flowchart of the modified code (Author, 2024).

Six Zeugma mosaic images are selected to be digitally reproduced (**Figures 15, 16, 17, 18, 19, 20**).

Figure 15: The Gypsy Girl Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd century A.D (Wikimedia, 2024a).

Figure 16: The Dionysos Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd-3rd century AD (Wikimedia, 2024b).

Figure 17: The Acheloos Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd century AD (Wikimedia, 2024c).

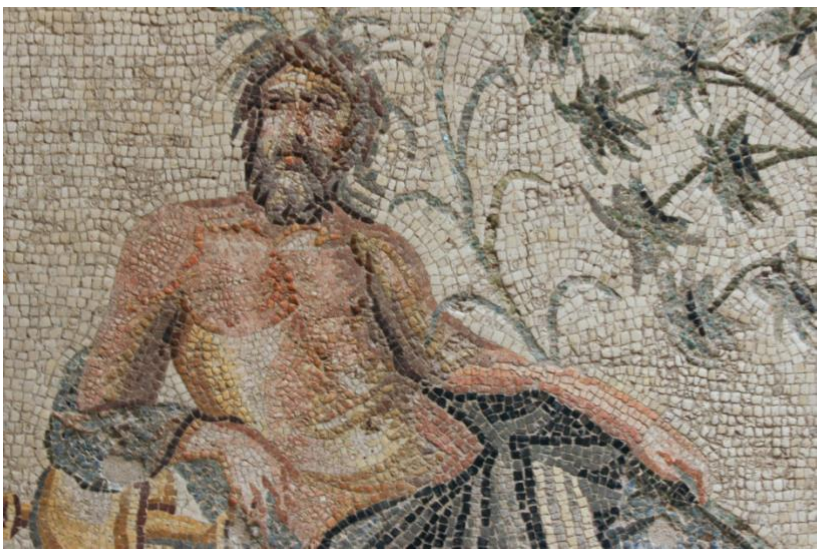

Figure 18: The Euphrates Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd-3rd century AD (Wikimedia, 2024d).

Figure 19: The Oceanus and Tethys Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd - 3rd century AD (Wikimedia, 2024e).

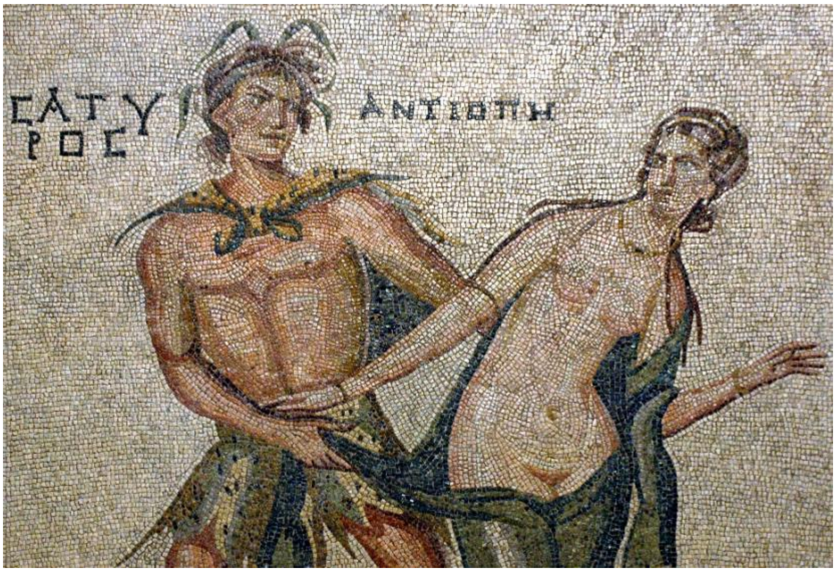

Figure 20: The Antiope and Satyros Mosaic, Zeugma Museum, Gaziantep, Türkiye, 2nd - 3rd century AD (Wikimedia, 2024f).

The algorithm that is used in this study, basically creates a grid system and fills each grid with suitable mosaic images based on their average red/green/blue channel values in order to form a bigger mosaic. For this purpose, while six Zeugma Mosaics were selected, 91 various Anatolian mosaic images (**Figure 21**) were selected from an online source manually to form a vast set for the algorithm, so that suitable brightness and color values can be selected from a wide range (Kültür Portalı, 2024). The images manually turned into square images to fit in the pixel grid without being distorted by the algorithm. The code was run in Processing 4 which is an open-source IDE and java-based language.

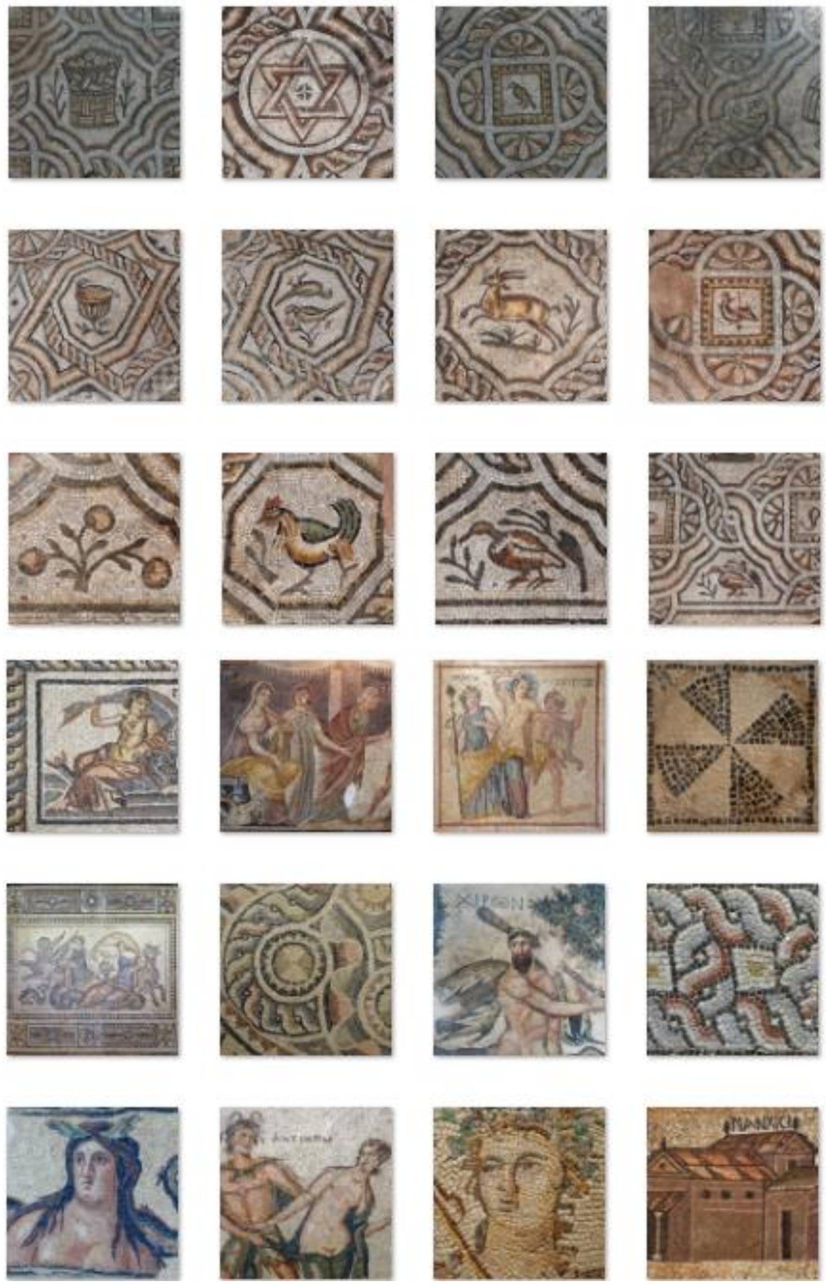

Figure 21: Some images from the Anatolian mosaics image set (Author, 2024).

3. RESULTS

The outcome mosaics that are digitally recreated by using smaller mosaic images as tiles (10*10 px.) based on their average red/green/blue channel values are presented below for each selected mosaic respectively (Figures 22 - 27).

Figure 22a: Digitally recreated the Gypsy Girl Mosaic based on red channel values (Author, 2024).

Figure 22b: Digitally recreated the Gypsy Girl Mosaic based on green channel values (Author, 2024).

Figure 22c: Digitally recreated the Gypsy Girl Mosaic based on blue channel values (Author, 2024).

Figure 23a: Digitally recreated the Dionysos Mosaic based on red channel values (Author, 2024).

Figure 23b: Digitally recreated the Dionysos Mosaic based on green channel values (Author, 2024).

Figure 23c: Digitally recreated the Dionysos Mosaic based on blue channel values (Author, 2024).

Figure 24a: Digitally recreated the Acheloos Mosaic based on red channel values (Author, 2024).

Figure 24b: Digitally recreated the Acheloos Mosaic based on green channel values (Author, 2024).

Figure 24c: Digitally recreated the Acheloos Mosaic based on blue channel values (Author, 2024).

Figure 25a: Digitally recreated the Euphrates Mosaic based on red channel values (Author, 2024).

Figure 25b: Digitally recreated the Euphrates Mosaic based on green channel values (Author, 2024).

Figure 25c: Digitally recreated the Euphrates Mosaic based on blue channel values (Author, 2024).

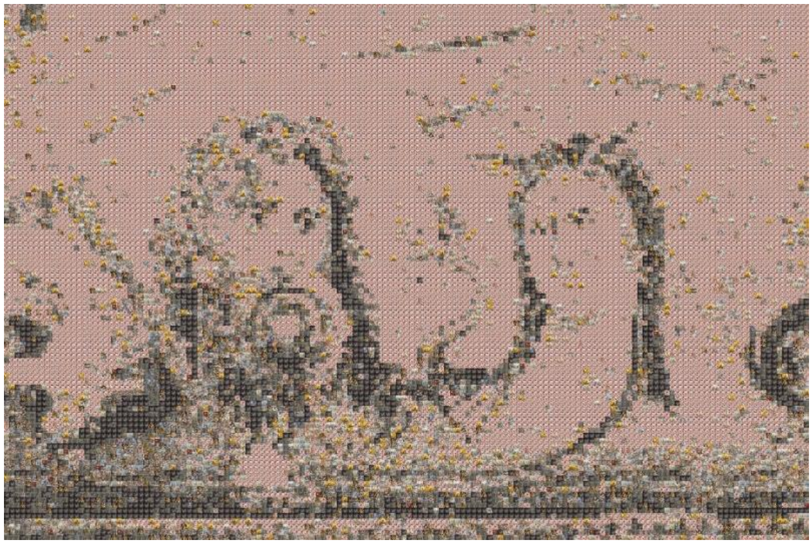

Figure 26a: Digitally recreated the Oceanus and Tethys Mosaic based on red channel values (Author, 2024).

Figure 26b: Digitally recreated the Oceanus and Tethys Mosaic based on green channel values (Author, 2024).

Figure 26c: Digitally recreated the Oceanus and Tethys Mosaic based on blue channel values (Author, 2024).

Figure 27a: Digitally recreated the Antiope and Satyros Mosaic based on red channel values (Author, 2024).

Figure 27b: Digitally recreated the Antiope and Satyros Mosaic based on green channel values (Author, 2024).

Figure 27c: Digitally recreated the Antiope and Satyros Mosaic based on blue channel values (Author, 2024).

It is seen that as the grid size increases, details of the main mosaic become less visible, however details of the small images become more visible, as expected (**Figures 28, 29**).

Figure 28a: Digitally recreated the Gypsy Girl Mosaic based on green channel values, with 10x10 pixel sizes (Author, 2024).

Figure 28b: Digitally recreated the Gypsy Girl Mosaic based on green channel values, with 50x50 pixel sizes (Author, 2024).

Figure 29a: Digitally recreated the Acheloos Mosaic based on red channel values, with 10x10 pixel sizes (Author, 2024).

Figure 29b: Digitally recreated the Acheloos Mosaic based on red channel values, with 50x50 pixel sizes (Author, 2024).

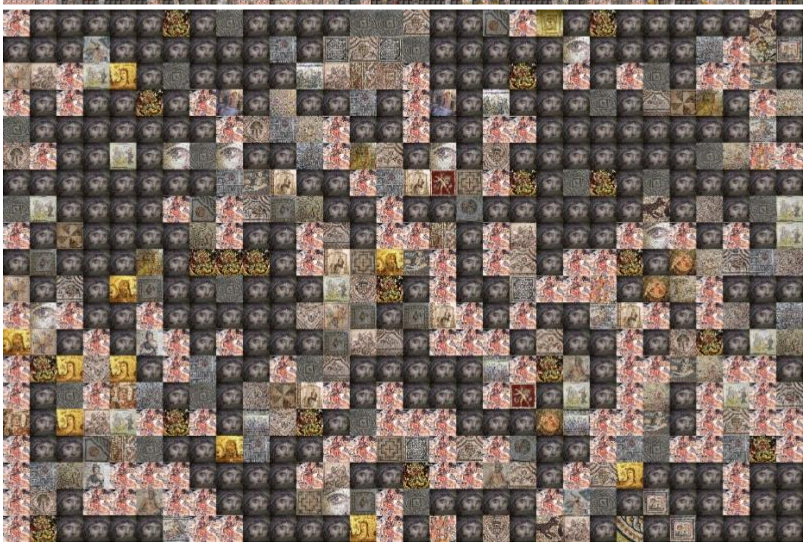

Figure 29c: Digitally recreated the Acheloos Mosaic based on red channel values, with 100x100 pixel sizes (Author, 2024).

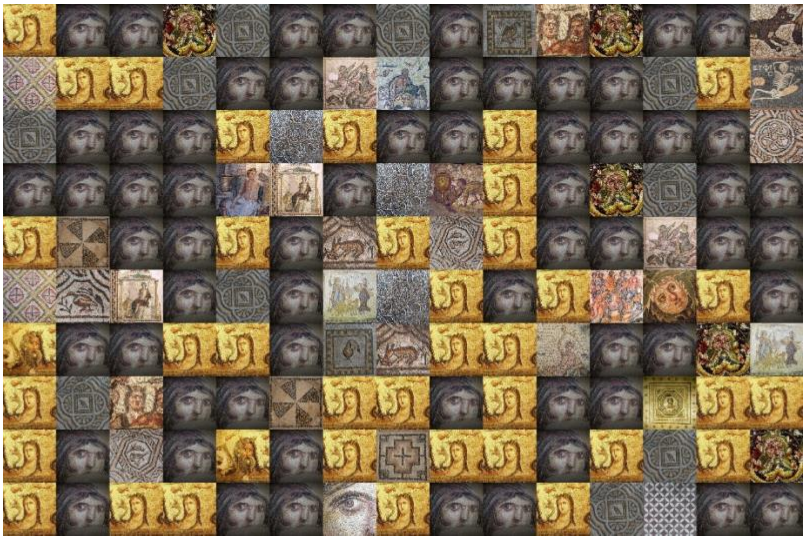

Figure 29c: Digitally recreated the Gypsy Girl Mosaic based on green channel values, with 100x100 pixel sizes (Author, 2024).

5. CONCLUSION

Through the use of contemporary computational tools, this study reinterprets a selection of the Zeugma mosaics. The project creates coherent digital artworks that preserve the integrity of traditional mosaic art while introducing modern digital skills. It achieves this by using an algorithm to match the RGB color values of smaller mosaic images with corresponding areas of a larger image. The photo-mosaic method, with the sample algorithm of Daniel Shiffman's 'Obama Mosaic' code, proved effective in generating aesthetically pleasing recreations of the original mosaic photographs. The algorithm mimics the original by dividing the canvas into a grid and selecting suitable mosaic pictures based on RGB values.

This study presents the possibilities of artistic creativity and cultural preservation, reinterpreting mosaics by digitally conserving their features. Furthermore, it merges conventional mosaic techniques with contemporary computational approaches, exploring new potentials for artistic expression. By demonstrating how computational methods can be used to reinterpret ancient art forms, the study contributes to the growing field of digital craftsmanship, showcasing its creative potential.

Looking forward, this approach could be further developed to enhance the precision and variety of mosaic recreations. Additionally, this method could be applied in educational settings, offering students hands-on experience with algorithmic art and cultural heritage preservation. Beyond mosaics, similar techniques could be adapted to reinterpret other traditional crafts, such as textiles or stained glass, by using computational tools to explore their patterns and colors in new ways. The fusion of digital and traditional techniques opens the door for broader applications in virtual museums, digital conservation efforts, and interactive art exhibits, expanding the role of technology in both preserving and reimagining cultural heritage.

Conflict of Interest Statement

The manuscript is entitled "From Mosaics to Pixels: Reinterpretation of Selected Zeugma Mosaics" has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

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