Semi Artificial Intelligent Graphics Design with Cylindrical Surface Test Case

M. Nuruzzaman, Ph.D.

Electrical Engineering Department, King Fahd University of Petroleum and Minerals,
Dhahran 31261, Saudi Arabia.

E-mail: nzaman@kfupm.edu.sa
mzamandr@gmail.com

ABSTRACT

Lately machine learning and artificial intelligence (ML/AI) are occupying the forefront of hi-tech industry. Whether local or global brand, visual content of an image communicates emotionally and psychologically with end-product users that is why graphics design receives so much importance in advertisement, social media, and trending campaign of any sort. Contemporarily image designer has to convey the idea of brand owner and campaigner through digital analytic tools. Intelligence or artificial intelligence (AI) may facilitate the visual content design. Imagery product is quintessential to social media, advertising, education, corporate business presentation, and many more high-tech products. Complete transition to AI designed visual system may not be fully pragmatic obviously for human cost, affordability, and available skill-set reasons. The semi artificial intelligence in visual content design might be effective during this transition.

(Keywords: artificial intelligence, AI, graphics design, visual art)

INTRODUCTION

Artificial intelligence (AI) and machine learning (ML) are revolutionizing many aspects of online and offline activities. Traditional approaches of solving science and engineering problems are disrupted by AI [1]-[4],[9]-[12]. The world is at the beginning of the fourth industrial revolution through the innovations of AI, robotics, the internet of things (IoT), and three-dimensional (3D) printing. Figure 1 depicts the fundamental strategy behind AI based systems.

Areas of implementation can be any physical application for example building a 3D printed house, manufacturing a 3D printed car, watching someone over the internet, tracking drones, etc. These are just a few samples of thousands of industrial applications.

In any job with human-in-the-loop decisions, we may ask how are these decisions made? Mostly, the are based on experience and professional judgement. These experiences indicate that similar events must be available in human brain or in other words memory in the case of machine learning that translates to event data. Event data needs to be collected for a particular application and then extrapolated based on user requirements. If the problem to be solved is open in nature, even the machine itself cannot be programmed because algorithm also has its limitation.

Figure 1. Strategy Behind Artificial Intelligence.

Graphics design is an artistic activity. First of all the user has to have a picturesque idea for a particular objective whether demonstration or business purpose. That idea is then translated to digital imagery through available graphics design tools. The advent of powerful computer processors forces us to think about all-too-familiar graphics design in a different perspective. Why not develop an algorithm or semi AI on behalf of us? There is a moral issue; if all freedom of design is handed over a computer, the image designer has little role to play. Instead, a partial algorithm-partial human approach would find a balance of the moral issue.

As far as Figure 1 is concerned, the human brain control be fully surrendered to a robot in an artificially intelligent environment. A robot decides graphics or extrapolation design from known data base. If the robot takes over entire degrees of freedom for visual design, there is no guarantee for tangible results because robotic intuition and user-requirement may not reach confluence. That is why complete AI systems may suffer limitations. Human element intervention may overcome the limitation. Some might argue, robotic automation also needs technical personality needless to mention that is one kind (e.g., robotic science and engineering personnel) and they have little to do with graphics design.

GRAPHICS DESIGN DIGITAL ANALYTICS

A graphically designed image is a true color digital image which has three color component matrices – red, green, and blue symbolically $r[m,n]$, $g[m,n]$, and $b[m,n]$ respectively, each of which is identical in size (or $M \times N$) and bears image intensity information that is any digital graphics is just the matrix triplet:

$$\begin{Bmatrix} r[m,n] \\ g[m,n] \\ b[m,n] \end{Bmatrix}$$

as is presented in Figure 2 [5]-[8].

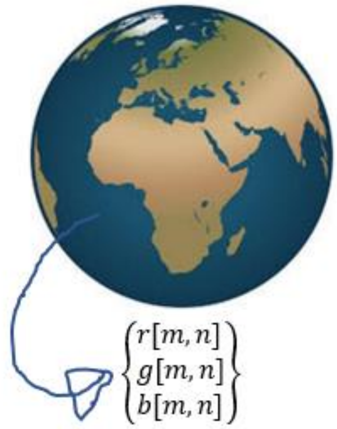

Figure 2. Triplet Point Formation at any point on an Image.

Both the coordinate $[m,n]$ and intensity functions $r[m,n]$, $g[m,n]$, or $b[m,n]$ are discrete in nature. Any three-dimensional image is mapped on a two-dimensional perspective and the triplet is just the end-product. The discretization is empirically linked by the following relationships:

$x = m\Delta x$,

$y = n\Delta y$, and

$f(x,y) = i\Delta f(x,y) = f[m,n]$.

where Δx and Δy are related to image DPI (dot per inch) and pixel capacity during screenshot. The x and y are image width and height directed coordinates respectively and i refers to intensity level storage in terms of bytes. Each of the three components in the triplet follows the analytics of $f[m,n]$.

DIGITAL MAPPING OF IMAGES

Digital mapping of images needs projecting one digital zone to another and commonly encountered ones are the geometric ones as follows below.

Translation: Any pixel coordinate $[m,n]$ is translated at $[m_0, n_0]$ by $m' = m_0 + m$ and $n' = n_0 + n$.

Scaling: Any pixel coordinate $[m, n]$ is scaled by factors a and b along the width and height directions of the image respectively by:

$$\begin{Bmatrix} m' = am \\ n' = bn \end{Bmatrix}$$

or in matrix form by transform vector

$$T = \begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix}.$$

Horizontal Skewing: Pixel coordinate transform relationship:

$$\begin{Bmatrix} m' = m + n \tan \phi \\ n' = n \end{Bmatrix}$$

or T vector

$$\begin{bmatrix} 1 & \tan \phi \\ 0 & 1 \end{bmatrix}$$

skews an image horizontally.

Vertical Skewing: Pixel coordinate transform relationship:

$$\begin{Bmatrix} m' = m \\ n' = m \tan \phi + n \end{Bmatrix}$$

or T vector $\begin{bmatrix} 1 & 0 \\ \tan \phi & 1 \end{bmatrix}$

skews an image vertically.

Rotation: Pixel coordinate $[m, n]$ rotated by an angle ϕ is given by:

$$\begin{bmatrix} m' \\ n' \end{bmatrix} = \begin{bmatrix} \cos \phi & \sin \phi \\ -\sin \phi & \cos \phi \end{bmatrix} \begin{bmatrix} m \\ n \end{bmatrix}$$

where $T = \begin{bmatrix} \cos \phi & \sin \phi \\ -\sin \phi & \cos \phi \end{bmatrix}$.

Interpolation: Pixel mappings translation to rotation are relevant to geometrical coordinates. How about the image intensity? Interpolation takes care of image intensity values. The three commonly used interpolation schemes are:

$$\begin{Bmatrix} \text{nearest neighborhood interpolation} \\ \text{linear interpolation} \\ \text{bicubic interpolation} \end{Bmatrix},$$

out of which nearest neighborhood and linear counterparts are extensively applied considering 2D image elements [7]-[8]. Extra contribution is needed for three-dimensional counterpart which we explain in next section.

INTERPOLATION IN 3D

The two interpolation schemes are now explained with theoretical details.

Nearest Neighborhood*:*

The 2D counterpart is addressed in [5]-[8] which in essence treats unity pixel separation and regular digital molecule; for artificial intelligence, general 3D counterpart is necessary which may not be regular. Figure 3 depicts the four intensities arising from four irregular digital molecules.

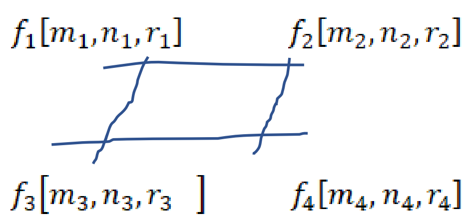

Figure 3. Four Image Intensities on Four Irregular Digital Molecules.

What is the challenge here? The decision which intensity is closest to a general point $[m', n', r']$ is sought. The relevant 3D logic is as follows:

$$if\ m' > \frac{m_1 + m_2}{2}$$

then $m_{12}' = m_2$ else $m_{12}' = m_1$

$$if\ m' > \frac{m_3 + m_4}{2}$$

then $m_{34}' = m_4$ else $m_{34}' = m_3$

$$if \;\; m' > \frac{m_{12}' + m_{34}'}{2}$$

then $m' = m_{34}'$ else $m' = m_{12}'$

similar comparison is also applied to n and r directions.

Trilinear: Rigorous treatment for bilinear counterpart is found in [7]-[8]. AI needs trilinear interpolation not necessarily aligning with the coordinate system of figure 3. Let us say another 3D coordinate system intensity molecules are like the Figure 4.

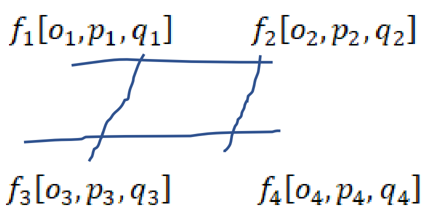

Figure 4. Four Image Intensities on Four Irregular Digital Molecules in Another System.

We derived the trilinear interpolation which needs a series of substitutions as follows:

Linearity along $o = o'$ for points 1 and 2:

$$f_{12}[o', p_5, q_5] =$$

$$\frac{f_2[o_2, p_2, q_2] - f_1[o_1, p_1, q_1]}{o_2 - o_1}(o' - o_1) + f_1[o_1, p_1, q_1]$$

Where:

$$k_1 = \frac{ó - o_1}{o_2 - o_1}$$

$$p_5 = k_1(p_2 - p_1) + p_1$$

$$q_5 = k_1(q_2 - q_1) + q_1$$

Linearity along $o = o'$ for points 3 and 4:

$$f_{34}[o', p_6, q_6] =$$

$$\frac{f_4[o_4, p_4, q_4] - f_3[o_3, p_3, q_3]}{o_4 - o_3}(o' - o_3) + f_3[o_3, p_3, q_3]$$

Where:

$$k_2 = \frac{ó - o_3}{o_4 - o_3}$$

$$p_6 = k_2(p_4 - p_3) + p_3$$

$$q_6 = k_2(q_4 - q_3) + q_3$$

Linearity along $p = p'$ for $f_{12}[o', p_5, q_5]$

and

$f_{34}[o', p_6, q_6]$:

$$f_{1234}[o', p', q_7] =$$

$$\frac{f_{34}[o', p_6, q_6] - f_{12}[o', p_5, q_5]}{p_6 - p_5}(p' - p_5) + f_{12}[o', p_5, q_5]$$

Where:

$$k_3 = \frac{p' - p_5}{p_6 - p_5}$$

$$q_7 = k_3(q_6 - q_5) + q_5$$

Linearity along $o = o'$ for points 1 and 3:

$$f_{13}[o', p_8, q_8] =$$

$$\frac{f_3[o_3, p_3, q_3] - f_1[o_1, p_1, q_1]}{o_3 - o_1}(o' - o_1) + f_1[o_1, p_1, q_1]$$

Where:

$$k_4 = \frac{ó - o_1}{o_3 - o_1}$$

$$p_8 = k_4(p_3 - p_1) + p_1$$

$$q_8 = k_4(q_3 - q_1) + q_1$$

Linearity along $o = o'$ for points 2 and 4:

$$f_{24}[o', p_9, q_9] =$$

$$\frac{f_4[o_4, p_4, q_4] - f_2[o_2, p_2, q_2]}{o_4 - o_2}(o' - o_2) + f_2[o_2, p_2, q_2]$$

Where:

$$k_5 = \frac{ó - o_2}{o_4 - o_2}$$

$$p_9 = k_5(p_4 - p_2) + p_2$$

$$q_9 = k_5(q_4 - q_2) + q_2$$

Linearity along $p = p'$ for $f_{13}[o', p_8, q_8]$ and $f_{24}[o', p_9, q_9]$:

$$f_{1324}[o', p', q_{10}] =$$

$$\frac{f_{24}[o', p_9, q_9] - f_{13}[o', p_8, q_8]}{p_9 - p_8}(p' - p_8) + f_{13}[o', p_8, q_8]$$

Where:

$$k_6 = \frac{p' - p_8}{p_9 - p_8}$$

$$q_{10} = k_6(q_9 - q_8) + q_8$$

Linearity along $q = q'$ from $f_{1234}[o', p', q_7]$ and $f_{1324}[o', p', q_{10}]$:

Analogous expression is:

$$\frac{f_{1324}[o', p', q_{10}] - f_{1234}[o', p', q_7]}{q_{10} - q_7}(q' - q_7) + f_{1234}[o', p', q_7]$$

which is basically $f[o', p', q']$ and which we wish to determine.

SURFACE PAINTING OF AN IMAGE

Painting an image by using digital graphics tools certainly simulates the action of an artist. In contemporary photoshops like adobe, image layer after layer is generated manually and checked the acceptability visually.

An algorithm can replace the manual manipulation which necessitates to use a surface painting.

The image we perceive is 2D one and often times the surface is a 3D object. The challenge here is to map a 2D surface onto a 3D one. With increased dimension, unwanted imagery appears due to openness of the problem. Figure 5 depicts the conversion from a 2D intensity f to 3D g.

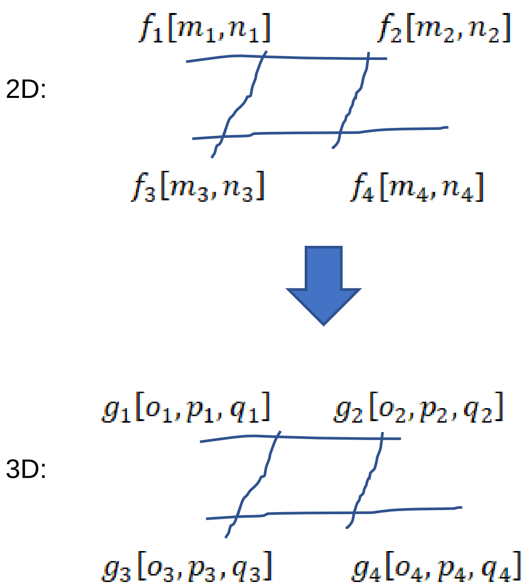

Figure 5: Conversion of a 2D Infinitesimal Surface to a 3D one.

A coherent stratagem is required for the conversion and the proposition is parametric transform. For instance, change of $f_1[m_1,n_1]$ to $f_2[m_2,n_2]$ must correspond to change of $g_1[o_1,p_1,q_1]$ to $g_2[o_2,p_2,q_2]$ regarding both the coordinate and intensity context.

A parameter k is introduced which is in [0,1]. By all sense k=0 and k=1 mimic the beginning and ending of the transform respectively. Within the bounds of k, uniform or nonuniform discretization is likely for graphics mapping.

A numerical example: Suppose a tiny zone on a 2D image is having the following non rectangular surrounding coordinates:

[8,12]	[13,15]
[3,5]	[4,9]

Let us say 4 and 5 grid points in the image width and height directions are chosen respectively and the grid points then become:

Along the width direction:

[8,12]	[29/3,13]	[34/3,14]	[13,15]
[3,5]	[10/3,19/3]	[11/3,23/3]	[4,9]

where parameter k changes as 0, 1/3, 2/3, and 1 respectively.

Along the height direction:

[8,12]	[29/3,13]	[34/3,14]	[13,15]
[27/4,41/4]	[97/12,34/3]	[113/12,149/12]	[43/4,27/2]
[11/2,17/2]	[13/2,29/3]	[15/2,65/6]	[17/2,12]
[17/4,27/4]	[59/12,8]	[67/12,37/4]	[25/4,21/2]
[3,5]	[10/3,19/3]	[11/3,23/3]	[4,9]

where parameter k changes as 0, 1/4, 2/4, 3/4, and 1, respectively.

Again, assume that the previous tiny 2D zone is mapped onto the following 3D patch:

[0,3,5]	[1,4,7]
[2,5,8]	[3,7,9]

Then the coordinate evolvement is as follows:

Along the width direction:

[0,3,5]	[1/3,10/3,17/3]	[2/3,11/3,19/3]	[1,4,7]
[2,5,8]	[7/3,17/3,25/3]	[8/3,19/3,26/3]	[3,7,9]

where parameter k changes as 0, 1/3, 2/3, and 1 respectively.

Along the height direction:

[0,3,5]	[1/3,10/3,17/3]	[2/3,11/3,19/3]	[1,4,7]
[1/2,7/2,23/4]	[5/6,47/12,19/3]	[7/6,13/3,83/12]	[3/2,19/4,15/2]
[1,4,13/2]	[4/3,9/2,7]	[5/3,5,15/2]	[2,11/2,8]
[3/2,9/2,29/4]	[11/6,61/12,23/3]	[13/6,17/3,97/12]	[5/2,25/4,17/2]
[2,5,8]	[7/3,17/3,25/3]	[8/3,19/3,26/3]	[3,7,9]

where parameter k changes as 0, 1/4, 2/4, 3/4, and 1, respectively.

What is the implication of this numerical example? In order to implement AI based graphics, a 2D molecule is mapped onto a 3D one for instance the 2D patch cornered by

[8,12] [29/3,13]

[27/4,41/4] [97/12,34/3]

is painted onto the 3D patch cornered by

[0,3,5] [1/3,10/3,17/3]

[1/2,7/2,23/4] [5/6,17/3,25/3].

where the image segment, 2D patch, 3D patch, and parameter directives are all user or robot chosen.

ALGORITHM FOR DIGITAL PAINTING

AI or robot based digital image painting requires an algorithm which is described as follows:

1) acquire the image (can be from digital camera, scanner, or handheld device, usually the image is in popular format jpeg or png),

2) convert the acquired image into true color or red-green-blue (known as rgb) form so that matrix triplet concept can be applied,

3) split the triplet into basic $r[m,n]$, $g[m,n]$, and $b[m,n]$ components,

4) select the zone on the 2D image, the selection is done by user or in case of AI by a robot,

5) parameterize the zone both along the image width and height directions,

6) determine the corresponding 3D coordinates of the zone from parametric representations,

7) apply 3D interpolation on the 3D parametric zone to each of the three image components $r[m,n]$, $g[m,n]$, and $b[m,n]$,

8) apply inverse interpolation to check digital domain consistency,

9) combine the three image components as a triplet for the digitally painted counterpart,

10) finally, exercise some view angle on the 3D surface to obtain the end 2D imagery product.

A 3D image has infinite views, this also brings some complexity in the implementation. Frequently, an acquired image employs view angle set by image display graphics. It is better to exercise the same view angle while implementing a 3D graphics else a perspective transformation will be required.

In case of multiple images algorithmic steps 1 through 10 are equally applicable to each one.

TEST CASES

To test the suitability of the AI or algorithmic digital image painting, assume that single or multiple images are to be painted on a cylindrical surface.

The contemporary approach is graphics designer takes the image into photoshop and manipulates segment and arc of the cylinder manually to provide specific bent, but earlier quoted algorithm is applied to conduct the image painting action.

Test images are required and Figures 7(a)-(d) are employed for the purpose namely Kids, Tulips, Water Lily, and Text images respectively. In order to display any 3D image, view angle (azimuth, elevation) = (ϕ, θ) as depicted in figure 6 is mandatory. The view coordinate $(-37.5^0, 30^0)$ is chosen to project the 3D painting on a 2D plane in the following results.

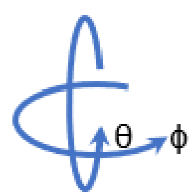

Figure 6: View Angle Parameters.

Cylindrical parameter selection is necessary too. Random cylindrical radius and height are chosen. Over the cylindrical segment the image painting starting angle and width of the image as angular spread need to be chosen along the ϕ direction which are chosen randomly as well.

Single Image Case: The Kids image is surface painted based on the following parameters:

starting angle for the image in degrees: 40^0,

spanning angle of the image on cylindrical surface: 70^0,

cylinder radius: 3, and

cylinder height: 4.

Figure 7(a)-(d): Four Test Images Employed for Surface Painting.

Figure 8 depicts the Kids image painting employing the AI approach.

Figure 8: A Single Image Painted on a Cylindrical Surface.

Double Image Case: The Water Lily and Kids images are surface painted based on the following parameters:

starting angle for the images in degrees: 0^0 and 90^0,

spanning angle of each image on cylindrical surface: 60^0,

cylinder radius: 3, and

cylinder height: 4 respectively.

Figure 9 depicts the Water Lily and Kids images' painting employing the AI approach, respectively.

Figure 9: Two Images Painted on a Cylindrical Surface.

Triple Image Case: The Tulips, Water Lily, and Kids images are surface painted based on the following parameters:

starting angle for the images in degrees: 0^0, 70^0, and 140^0,

spanning angle of the image on cylindrical surface: 60^0 each,

cylinder radius: 3, and

cylinder height: 4 respectively.

Figure 10 depicts the AI surface painted result on the Tulips, Water Lily, and Kids images respectively.

Figure 10: Three Images Painted on a Cylindrical Surface.

Quadruple Image Case: The Text, Tulips, Water Lily, and Kids images are surface painted based on the following parameters:

starting angle for the image in degrees: 0^0, 70^0, 140^0, and 210^0,

spanning angle of the image on cylindrical surface: 60^0 each,

cylinder radius: 3, and

cylinder height: 4 respectively.

Application of the AI employed image is seen in Figure 11.

Figure 11: Four Images Painted on a Cylindrical Surface.

CONCLUSION

Semi Artificial Intelligence (AI) is applied to graphics design from a balanced perspective. An effort has been made to implement algorithmically derived graphics design where literally full control is not surrendered to a machine or robot. To facilitate the process, 2D to 3D image intensity conversion through parametric approach is derived. At the heart of the conversion, finite difference tactic plays an important role which takes care of imagery spatial domain or discrete intensity of any sort. Nevertheless, a thorough algorithm is presented to execute the semi artificial intelligence. As a token graphics design example, cylindrical surface painting is considered. Visual perception on specific view angle self explains the algorithmic effectiveness. One drawback of the process is the overall computing burden. As far as higher processor speed evolvement is concerned, the semi artificial intelligence tool is useful despite being computationally intensive.

ACKNOWLEDGEMENT

The author acknowledges King Fahd University of Petroleum and Minerals (KFUPM) for providing the library and computer facilities necessary for conducting this research.

REFERENCES

1. Flach, P. 2012. *Machine Learning – The Art and Science of Algorithms that Make Sense of Data*. Cambridge University Press: New York, NY.

2. Harrington, P. 2012. *Machine Learning in Action*. Manning Publications Co.: New York, NY.

3. Lucci, S. and D. Kopec. 2016. *Artificial Intelligence in the 21st Century", Second Edition*. Mercury Learning and Information: Boston, MA.

4. Kopec, D., S. Shetty, and C. Pileggi. 2014. *Artificial Intelligence Problems and Their Solutions*. Mercury Learning and Information: Boston, MA.
5. Nuruzzaman, M. 2011. "Digitally Animated Overture using Skewing in Two Dimensions", *Pacific Journal of Science and Technology*. 12(1):252–259.

6. Nuruzzaman, M. 2009. "Translation Overture Effect through Polar Equations in Two Dimensional Digital Animations". *Pacific Journal of Science and Technology*. 10(1):300–309.

7. Russ, J.C. 1999. The Image Processing Handbook. CRC Press: Boca Raton, Florida.

8. Nuruzzaman, M. 2012. *Digital Image: Theories, Algorithms, and Applications*. CreateSpace: Washington, D.C.

9. Shaparau, D., M. Pistore, and P. Traverso. 2008. “Fusing Procedural and Declarative Planning Goals for Nondeterministic Domains”. *Proceedings of the 23rd AAAI Conference on Artificial Intelligence*. Chicago, IL.

10. McCarthy, J. 2007. “From Here to Human-Level AI”. *Artificial Intelligence*. 171(18).

11. Diez, F.J. and M.J. Druzdzel. 2002. “Canonical Probabilistic Models for Knowledge Engineering”, Technical Report IA-02-01, Dpto. Inteligencia Artificial, UNED: Madrid, Spain.

12. Krizhevsky, A., A.I. Sutskever, and E. Hinton. 2012. “ImageNet Classification with Deep Convolutional Neural Networks”. *NIPS 12 Proceedings of the 25th International Conference on Neural Information Processing Systems*.

SUGGESTED CITATION

Nuruzzaman, M. 2022. “Semi Artificial Intelligent Graphics Design with Cylindrical Surface Test Case”. *Pacific Journal of Science and Technology*. 23(1): 47-56.

Pacific Journal of Science and Technology