New Design Ideas
Vol.6, No.3, 2022, pp.356-373

MEASURING THE INTERACTIVE LEVEL IN URBAN SPACES UTILIZING FUZZY INFERENCE SYSTEM

Suha Imad Aldobouni*, Ahmed Yousif Al-Omary

College of Engineering, University of Mosul, Iraq

Abstract. Interactive design is an important approach to outdoor spaces designed to increase excitement, fun, learning, enriches the sensory experience of users and increases their interaction by engaging the five senses. With the development of technology, people interact through virtual spaces more than they interact with each other in public spaces, so the designer seeks to increase the interaction of urban spaces by creating relationships between people and buildings. Thus, we have to ask some questions: First, which technology creates interactive urban spaces and encourages people to stay longer among them? Also, which one of these techniques is the best? After reviewing several previous studies, it was found that there are large numbers of techniques that can be used to enhance interaction in urban areas. Therefore, the obstacle that faced the study was the multiplicity of interactive methods used in outdoor spaces, and the inability to know which of them achieves greater interaction. Thus, the aim of this study was to find a way to assess which of these ideas would achieve greater interaction. The study presented a smart proposal to evaluate the interaction of several models of global urban space projects using the fuzzy inference system. In addition, to conduct statistical tests to verify the efficiency of the utilized smart system, the results showed a discrepancy in the degree of interaction between projects. Finally, this study is a way to measure the interaction of urban projects to find out which of the alternatives is the best to be implemented.

Keywords: *Interactive design, idea generation, interactive technologies, interactive evaluation of outdoor spaces.*

Corresponding Author: *Suha Imad Aldobouni, College of Engineering, University of Mosul, Iraq, e-mail: suhaimad91@gmail.com*

Received: *16 May 2022;* ***Accepted****: 31 August 2022;* ***Published:*** *8 December 2022.*

1. Introduction

Interactive design considered as one of the modern design approaches that have gained a clear interest in the field of outdoor spaces because of the changing needs of societies and the great and noticeable development of technology. Nowadays, Information and Communication Technologies (ICTs) have spread extensively in everyday life in an unprecedented way. A great attention is paid to the ICTs while ignoring the social aspects. With the immersive invasion of internet as well as smartphones' applications and digital social networking, people become more socially connected through virtual spaces instead of meeting in physical public spaces (Abdel-Aziz *et al.,* 2016). Accordingly, in order to make an effective and energetic outdoor spaces designs, these new designs should keep pace with modern needs of the societies and with the new emerging developments in technology to be able to make designs that are attractive to the residents and providing a different sensory experience for people.

How to cite (APA):
Aldobouni, S.I., Al-Omary, A.Y. (2022). Measuring the interactive level in urban spaces utilizing fuzzy inference system. *New Design Ideas*, *6*(3), 356-373.

Interactive designs are based on increasing the elements of suspense, pleasure, learning, changing behavior, and enriching the users' sensory experience by engaging the five senses. Consequently, the general problem of this study arouses due to the fact that many cities suffer from the existence of un designed, dead, and ineffective urban spaces. Such places are not intended by the population and do not attract attention and may become hotspots for unwanted activities, which may cause many problems for these cities. As for the special problem, it was represented by two main points: the lack of full knowledge about the different ideas that contribute to the revival of ineffective urban outdoor spaces, and the lack of clear perceptions about the impact of technology on the ideas generating interactive outdoor spaces. Therefore, this study aims to explore and analyse interactive ideas, and ways of their implantation through traditional and digital technologies. Also, exploring formulas, and methods of generating them for the purpose of applying them in external spaces for the possibility of re-employment in the revival of urban outer spaces in contemporary cities. As well as, finding a model to evaluate (numerically) the reactivity of urban projects according to the ideas and methods which are used in them. In order to achieve the aim of the study, the research methodology was defined and represented by building a theoretical framework that defines the concept of interaction and interactive ideas and the means of their generation. Five main features were extracted. As for the practical part, it includes two phases. The first is the selection of fifty samples for interactive global external spaces. These samples were analyzed based on the five extracted features. The second phase includes measuring the degree of reactivity of each chosen sample, using the proposed fuzzy inference system (FIS). In addition, for more Investigation the multiple simple linear regression equation was used to measure the extent of the effect of the extracted features in measuring the reactivity of the research samples. Also, the statistic T-test was applied to compare the significant differences among the analyzed samples. The results have shown the effectiveness of the selected features and the possibility of using them to increase interactivity in urban spaces, as well as, the efficiency of the fuzzy logic system to measure the degree of interactivity of external designs, finally the use of digital technologies generate more relatively interactive designs compared with those that depend on traditional techniques.

2. Related work

There are many studies mentioned methods of increasing interaction in outdoor spaces. Ritter (2000) mentioned that interaction increases as movement increases and he suggested a scale called the Paps (Physical Aesthetics Pleasantness Score) to measure the quality of the kinetic experience when using an interactive medium. The study of Bruder & Ucok, (2000) indicated different reactions of people towards art works. The study identified three types of reactions: evaluation, attraction, and storytelling. These responses were determined through observation. Also, Ali (2013) explained the importance of lighting in achieving interaction in External spaces. Huo (2016) presented design methods that make outer space an interactive space by linking the features of interactive design and methods of stimulating feelings in people such as raising curiosity, surprise and joy and making a mutual reaction between people and designs through the use of certain design methods such as combining two functions, shifting from the second dimension to the third dimension, reversing the function ... etc. Ahmed *et al*. (2018) explained in his study the importance of achieving kinetic interaction in

outdoor spaces through using advertisements. Dekel *et al*. (2005) suggested three projects which are: (sonic waterfalls, a musical chair, and intimate bench) to increase interaction in public spaces. Grønbæk (2012) discussed design issues in the development of playful outdoor interactive installations featuring kinesthetic interaction and immersive music experiences by using swing play. Ya-Ling et al. (2016) explained the importance of smart technologies to increase the interactive perception of space through the creation of a sensory experience through smart display units using hologram technology on top of a tower in outdoor spaces which is the landmark of tainan to represent its history and the events that have passed through it. Abdel-Aziz et al. (2016) emphasized the importance of technology in transforming dead spaces into interactive spaces through four elements as follows: Wi-Fi networks, digital interactive media facades, interactive public displays, and smartphones' applications in public spaces. The element Which will play major roles in the public space categorized into five areas: culture and art, education, planning and design, games and entertainment, and information and communication. Schnabel & Karakiewicz (2007) proposed three designs, the first of which is an acoustic interaction using a noise barrier wall that interacts with the generated sound. This design used negative surrounding influences to generate positive vibes in the context of the city. Another proposed kinematic interaction analysis is through a system of self-opening blinds that interact with both pedestrian traffic and weather conditions to provide a comfortable environment in all conditions. As shown in the previous studies above, all studies showed great interest in the subject of interaction. Most studies presented designs that encourage interaction. Some studies dealt with observing and watching reactions to designs. All studies dealt with a specific aspect of interaction that was (auditory, visual, kinesthetic ... etc.). Thus, we need a method to measure the degree of interaction of all kinds mentioned in the previous studies, in order to choose the best design which can stimulate more interaction before starting the implementation process. This study included a proposal to use the fuzzy inference system to measure the degree of interaction of external spaces, as shown in paragraph (4-2).

3. Interactive landscape approach

What Is Interactive Landscape? This term was used in the urban environment to express the concept of mutual communication between people and landscape design which offer the opportunity to people to stay for longer time in landscape. Leaving them with a fresh and enjoying experience. Accordingly, interactive landscape should be responsive, active, sensitive, and in a constant dialogue with us as users or inhabitant (Huo, 2016). Theoretically, interactive landscape design is expected to solve the problem of mutual relationship between people and landscape environment (Li & Ding, 2014). Thus, a new name for landscapes appeared, which is "sensory landscapes" which were designed Specifically to stimulate the five senses (sight, hearing, touch, smell, and finally taste as in sensory gardens) (Ervin, 2018).

4. Materials and method

The methodology of this study included two phases. The first phase includes three stages which are (defining the features of the study, collecting the samples, extracting five features from the samples). The second phase describes the proposed fuzzy

inference system (FIS) which is used to calculate the degree of interactivity of the outer spaces.

4.1. First phase

As shown above, the first phase includes three stages which are (defining the features, collecting the samples, extracting five features from the samples).

a- Features definition: The features were extracted from previous studies, which have been utilized for analyzing the selected global examples. In this study five major features are used, and each feature consists of sub features, as explained below:

- The First feature is called "Generation of interactive ideas "which includes the following four sub features:
  a) Alternative's methods (Serrat, 2017).
  b) Relationships among shapes (Booth, 2011; Cani *et al*., 2008) .
  c) Ideas origin (Abazov, 2015; Najafi *et al.*, 2020) .
  d) Changes of properties (Karino *et al*., 2012; Lutyens, 2020; Proulx, 2020) .
- The Second feature is called "The influence of ideas on user "which includes the following two sub features.
  a) Excitement generation (Bruder & Ucok, 2000; Ritter, 2000; Gunes & Piccardi, 2005; Huo, 2016; Song & Huang, 2018).
  b) Sensations addition (Gunes & Piccardi, 2005) .
- The Third feature is called "Function of ideas "which includes the following six sub features.
  a) Entertaining (Grønbæk, 2012).
  b) Education (Elesapiens, 2018).
  c) Health (Schnabel & Karakiewicz, 2007).
  d) Commerce (Ahmed *et al*., 2018).
  e) Tourism (Ya-Ling *et al.*, 2016).
  f) Culture(Ya-Ling *et al*., 2016).
- The Fourth feature is called "Time to use the ideas "which includes the following two sub features:
  a) During the day (Guido, 2019).
  b) At night (Ali, 2013).
- The Fifth feature is called "The type of the technique being used "which includes the following five sub features:
  a) Optical techniques (CGTN, 2021; Guo *et al.*, 2008; Howard, 2019; Proulx, 2020).
  b) Kinematic techniques (Abdel-Aziz *et al.*, 2016; Ritter, 2000; Enas Salem, 2013).
  c) Hearing techniques (Ervin, 2018).
  d) Touching techniques (Lafitte, 2019).
  e) Sculptural techniques (Alfano, 2004; Coombs, 2001; Erman, 2018).
  f) Technologies that use water (Charles & Nicholas, 1988). Look at table 1 for more details.

b- Sample collection: Fifty samples were selected for interactive outdoor space projects from twenty-one different countries, namely (Netherlands, Romania,

France, Spain, Ireland, China, Emirates, Poland, South Korea, Australia, Canada, Russia, Portugal, Philippines, Italy, Denmark, South Africa, Austria, India, Japan, and United States). The samples are selected according to their importance, diversity, modernity of the techniques that designers have used, and the following criteria:

- The novelty of the samples selected to be limited to the time period from 2000 to 2020.
- The multiplicity of geographical locations in which these samples were carried out, and sometimes the same project was designed in more than one site.
- The diversity of the selected sample's function.
- Diversity of interactive technologies used in projects.
- Availability of literature, photos and videos about the selected interactive projects.

Table 1. Details of the extracted features

Major Features	Sub Features	Possible Value of Sub Features		
Generation of interactive ideas	Alternatives methods	different alternatives		
		the same item		
		inverse thinking		
		Thinking against laws		
		Scamper method	Substitute	Components
				Materials
			Combine	
			Adapt	Change function
				Use one part of another
			Magnify/ Modify	Change in scale
				Change in shape
				Attribute Adjustment
	Alternatives methods	Scamper method	Other Uses	
			Eliminate	Remove items
				simplification
			Revers	From inside to out
				From top to bottom
Generation of interactive ideas	Relationships among shapes	Two dimensions	Subtraction or addition	
			rotation	
			synthesis of the others	
		Three dimensions	extrusion	
			smoothing	
			transformation	
			Intervention	
	Ideas origin	Metaphor		
		Analogy		
	Changes of properties	Change transparency and reflectivity		
		Change using optical illusions		
		Change sound		
		Change light and color		
		re programable method to produce new interactive design		

The influence of ideas on user	Excitement generation	Excitement Curiosity	Form
			Scale
			Visible and invisible
			CombiningTwo Functions
			Reverse function
			Add and enhanced feeling
			one to one reaction
			instant reaction
			take the opportunity
		Possessive instinct	Vacancy
		Exploration instinct	Suspense
			puzzles
			strange shape
			Ambiguity
The influence of ideas on user	Excitement generation	Memory Recalling	Mental Image
			Effectiveness
			the meaning
			the sound
			Fragrances
			simulation a specific story or event
		Movement stimulation	Stimulate jumping
			walking or running
			Sudden stopped
			Stimulate climbing
		Attract attention and increase focus	Using light and color
			Using scale
			Using sounds
			Sudden movement
	Sensation's addition	Bring comfort and calm	Human scale
			Containment
			The calm lighting and colors
			Quiet voice
			Clarity
			Nature
		Feeling restless	Surprising item
			narrow places
			Uncommon shape
			Loud sounds
Function of ideas	Entertaining		
	Education		
	Health		
	Commerce		
	Tourism		
	Culture		
Time to use the ideas	During the day		
	At night		

The type of the technique being used	Optical techniques	Lighting	As an effect on the color of the elements
			Determine the shape
			A way to advertise and celebrate
			Laser shows (hologram)
			Led technologies
		Visual illusions	
		Augmented Reality	
	Kinematic techniques	Mechanical	
		Digital	
		Self-motion	
	Hearing techniques	Natural sounds like bird and water sounds	
		Artificial sounds such as music sounds	
	Touching techniques	Interactive screens	
		Sensors	
	Sculptural techniques		
	Technologies that use water		

Table 2. Information of interactive floors samples

No.	Name	Year and Location
1	Petar Zoranić Square and Šime Budini Plaza (Kostrenčić-Krebel, 2013)	Zadar in 2013
2	Artificial Urban Glaciers (Bored Panda, 2012)	Enscheda in 2012
3	Interactive playground design by Sensigom (FG Team, 2016)	France, Spain and Ireland in 2016
4	Miguel chevalier projects digital arabesques along the al majaz waterfront (Azzarello, 2014)	Sharjah in2014
5	Big Piano (Saraceni, 2018)	UK and Ireland in 2018
6	Guildhall square aglow (King, 2013)	London in 2008
7	Ground surrounded by water (Ahmed, 2019)	Dubai in 2018
8	Pavegen's floor tiles (Jordahn, 2017)	London in 2009
9	PARK TYCHY (Skitek, 2014)	Poland in 2014
10	The floor is lava (EPA, 2016)	South Korea in 2016

Table 3. Information of interactive ceilings samples

No.	Name	Year and Location
11	Host of Janet Echelman (Rosenfield, 2016)	London in 2016
12	Birdcages (Yoo, 2012)	Sydneyin 2009
13	Caitlnd Brown Cloud (Brown, 2012)	Canada, Moscowin 2012
14	Reflective Boxes (Hosmer, 2013)	Portugal in 2013
15	Drons (DAMODA, 2020)	China in 2020

Table 4. Information of interactive walls samples

No.	Name	Year and Location
16	Les Astronautes (Howarth, 2014)	Quebec in 2014
17	Maze of Mirrors (Yoo, 2013)	Sydney in 2013
18	Happy wall (PARADISE, 2019)	Canada in 2018
19	Climbing Walls at Maggie Daley Park (Dodge, 2015)	Shanghai in 2015
20	*Mirror Mirror* (Stewart, 2019)	Virginia in 2019
21	Rainbow maze (Stewart, 2017)	China in 2017
22	Interactive playground (FG Team, 2016)	France, Spain, Ireland in 2016
23	Interactive Running Track (Ong, 2017)	Philippines in 2017

Table 5. Information of interactive Street furniture samples

No.	Name	Year and Location
25	Musical swing (Bloom, 2016)	Canada in 2012
26	swing waterfall (wordlesstechteam 2012)	London in 2011
27	stringy yellow tube (JOHNSON, 2011)	Texas, Los Angeles in 2011
28	Dubai smiles (Erman, 2018)	Dubai, New York, Toronto in 2017
29	Color changing bubbles (Yoo, 2012)	France in 2012
30	fallen starsand Red dominoes (Frearson, 2011)	Portugal in 2011
31	Urban Reef (Deutscher, 2014)	Canada in 2014
32	Marbles of light (Roosegaarde, 2014)	Amsterdam in 2014
33	Animated fountain (Hamed, 2017)	China in 2017
34	Dancing fountain (Dombrowski , 2012)	Dubai in 2009
35	Giant Moving Head Steel (Yoo, 2011)	North Carolina in 2011
36	Topiary (Britannica, 2017)	Canada and Shanghai in 2000
37	Les Voyageurs (Smithe, 2017)	Marseille in 2013
38	Percussion (Company, 2016)	School playground, elderly center, tourist attraction in 2016
39	Crown Fountain (Giannetto, 2019)	Chicago in 2004
40	Swing Time (MacLeod, 2014)	Boston in 2014
41	The Bean (Giannetto, 2019)	Chicago in 2006
42	Nelson Mandela statue (Caboz,2018)	Howick in 2012
43	Be in the Weather (LUSIARDI, 2016)	Denmark in 2016
44	walking in the balloons (Neira, 2015)	Taipei in 2015
45	Street furniture in Seattle (MacLeod, 2014)	Seattle in 2014
46	Interactive Museum (KARAARSLAN, 2018)	Austria in 2018
47	interactive screen (CGTN, 2021)	China in 2020

Table 6. Information of interactive mix group samples

No.	Name	Year and Location
48	Dalston House (Frearson, 2013)	London in2013
49	Hologram (Thomas, 2017)	Japan in 2017
50	Theory (Guido, 2019)	India in 2019

- The different design positions of the selected samples, some of them are interactive floors and others are interactive ceilings or walls. Therefore, it divided into five groups according to the places where technologies are employed. As the first group included projects specialized in interactive floors, the second with interactive ceilings, and the third group was concerned with interactive walls, while the fourth group was concerned with furniture. Finally, the mix group, meaning that it is a wall and a floor together, or ceiling and a floor together…etc. Look at tables 2, 3, 4, 5, 6 for more details about samples.

c- Sample analysis: The samples were analyzed based on the five extracted features with their sub types from the theoretical study.

4.2. Second phase includes Fuzzy inference system description

Fuzzy logic is defined as a set of mathematical principles dependent on the degree of affiliation (membership values) to represent knowledge (Zadeh, 1965). His basic idea depends on the possibility of obtaining real values in the period between (0, 1). And not the same as binary logic, which is limited to one of the two values {True, False} or {0, 1}(Tamir *et al*., 2015).Fuzzy inference system was used to evaluate the degree of

reactivity in the outer spaces. According to the five features mentioned above, which were applied to fifty global samples. So that the degree of reactivity is limited between 50-100 degrees. As 50 represents the lowest degree of reactivity considering that all samples that were selected and analyzed have a limit of interactivity and 100 represents the highest degree of reactivity. And the degree of reactivity was calculated based on four main steps.

a- Input: The following five features has been entered:

- Generation of interactive ideas. Its values range from {1-7}.
- The influence of ideas on user. Its values range from {1-14}.
- Function of ideas. Its values range from {1-4}.
- Time to use the ideas. Its values range from {1-2}.
- The type of the technique being used. Its values range from {1-5} as shown in figure 1 below.

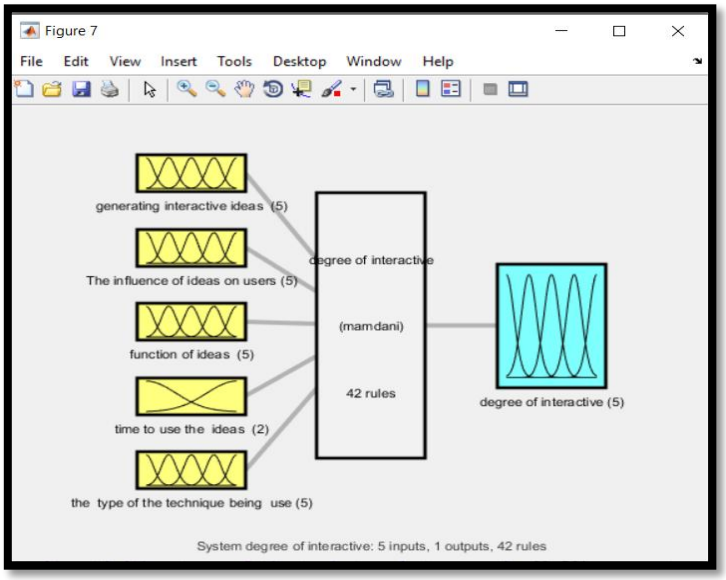

Figure 1. Inputs of the Fuzzy inference system

b- Fuzzy Sets: The Gaussian membership function was used because it gives more flexibility compared to the Triangular Membership Function and the Trapezoidal Membership Function. The fuzzy set for each of the (first, second, third and fifth inputs) have been divided into five parts, which are (very high, high, medium, low, very low), as shown in figures 2, 3, 4, 5.

c- Fuzzy inference system (FIS): 42 rules were used to obtain the outputs by adopting the Mamdani system.

d- Defuzzification: Cancellation fuzzification from membership function through the Defuzzification process to obtain output.

e- Graphical User interface (GUI): The graphical user interface is designed to create an interactive link between the proposed system and the user. To run this program, enter the values of the analysis criteria for sample in the suitable fields then click on run button. Thus, the degree of interaction will appear, as shown in figure 7.

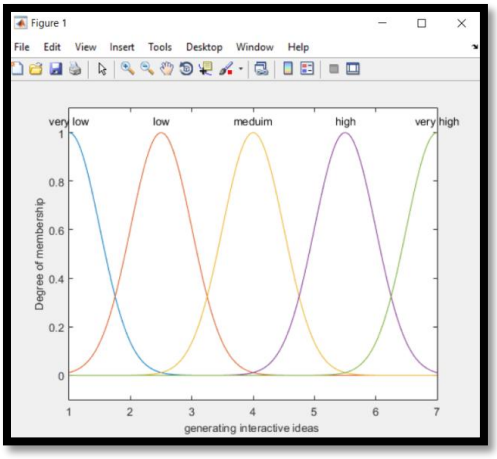

Figure 2. Fuzzy set of the first features

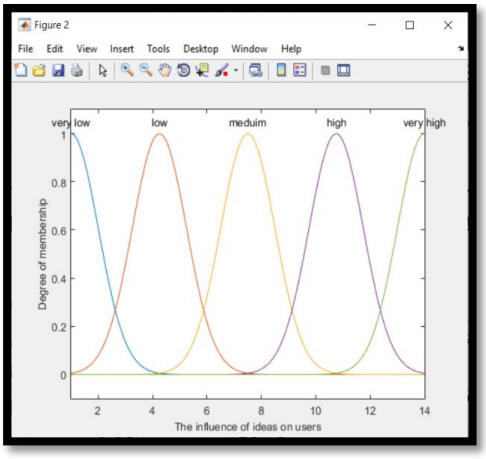

Figure 3. Fuzzy set of the second features

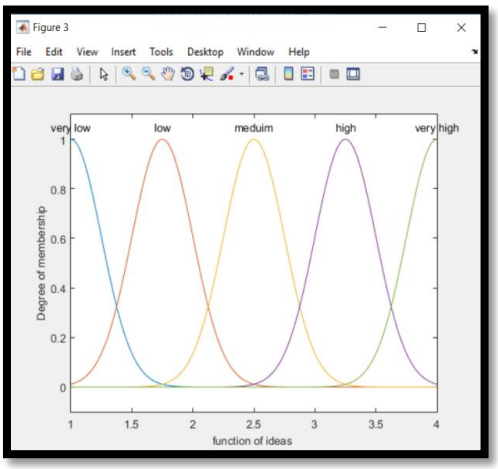

Figure 4. Fuzzy set of the third features

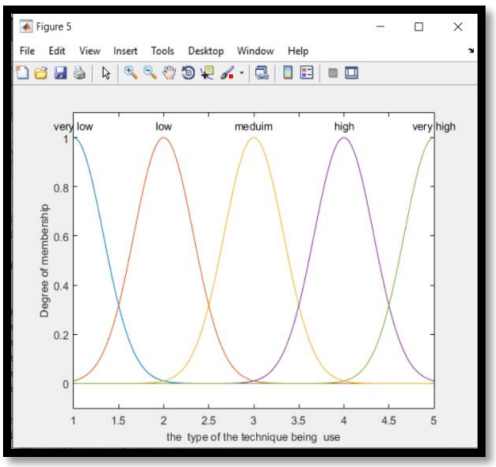

Figure 5. Fuzzy set of the fifth features

As for the fourth input, it was divided into two parts, which are (high, low) as shown in figure 6.

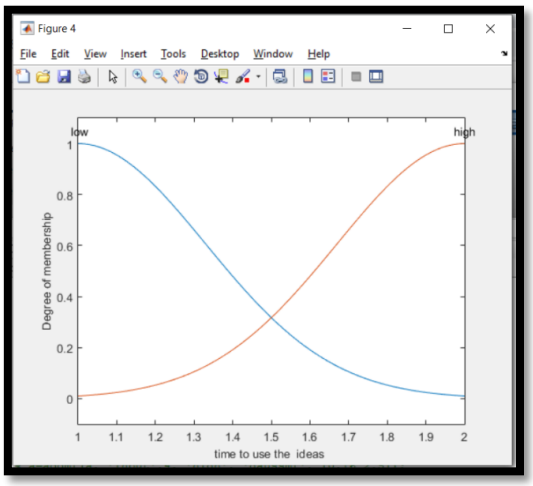

Figure 6. Fuzzy set of the fourth features

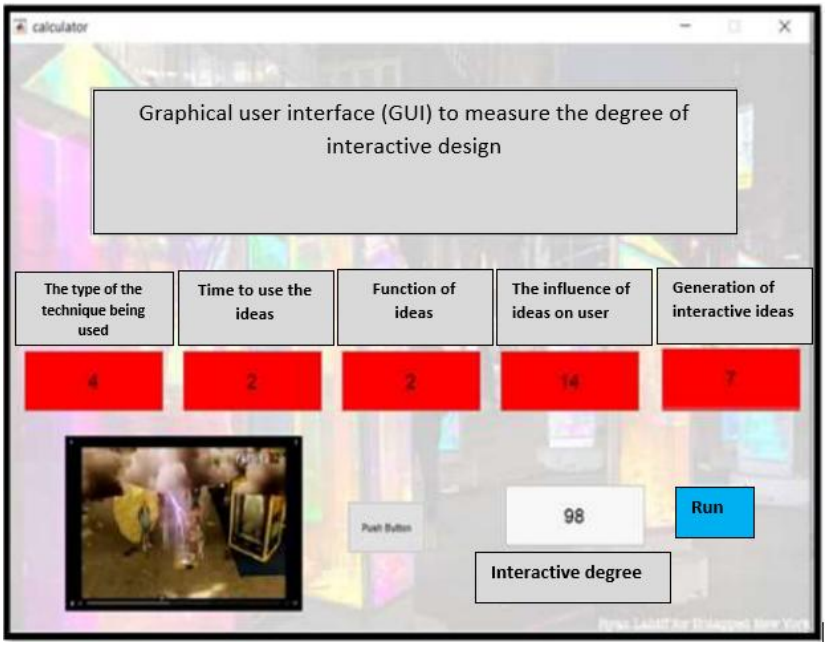

Figure 7. Graphical User interface (GUI)

5. Results and discussion

The results of the fuzzy inference system showed that there are differences in the interactive degrees of the selected samples, as shown in Table 5.

Table 5. Fuzzy inference system result

No	Degree of interactive	No	Degree of interactive
Sample 1	79.25	Sample 26	87.5
Sample 2	79.25	Sample 27	56.25
Sample 3	75	Sample 28	62.5
Sample 4	83.25	Sample 29	75
Sample 5	95	Sample 30	64.5
Sample 6	84	Sample 31	52
Sample 7	62.5	Sample 32	92.5
Sample 8	63	Sample 33	87.5
Sample 9	62.75	Sample 34	91.75
Sample 10	62.5	Sample 35	56.25
Sample 11	63	Sample 36	63
Sample 12	62.5	Sample 37	62.5
Sample 13	63.5	Sample 38	57
Sample 14	56.25	Sample 39	75
Sample 15	87.5	Sample 40	86
Sample 16	81.25	Sample 41	81.25
Sample 17	81.25	Sample 42	63
Sample 18	62.5	Sample 43	55.25
Sample 19	54	Sample 44	95.5
Sample 20	95.25	Sample 45	75
Sample 21	95.25	Sample 46	75
Sample 22	86	Sample 47	96
Sample 23	93.25	Sample 48	63
Sample 24	62.7	Sample 49	98
Sample 25	56.25	Sample 50	62.75

It is clear from table 5 that sample (49) - hologram technology- which creates virtual scenes, has obtained the highest interactive degree (98), and that sample (31)- urban reefs- obtained the lowest degree of interaction (52). The interaction degrees for the rest of the samples varied between these two values.

- The results showed that designs based on interactive digital technologies obtained higher degrees of interactivity compared to designs based on traditional technologies
- The results showed that sample (5) -piano floor- which uses digital interactive techniques is higher in the interactive value (95) than other floors, while sample (10) the lava floor got the lowest degree of interactivity (62.5) which uses traditional interactive techniques as shown in figure (8).

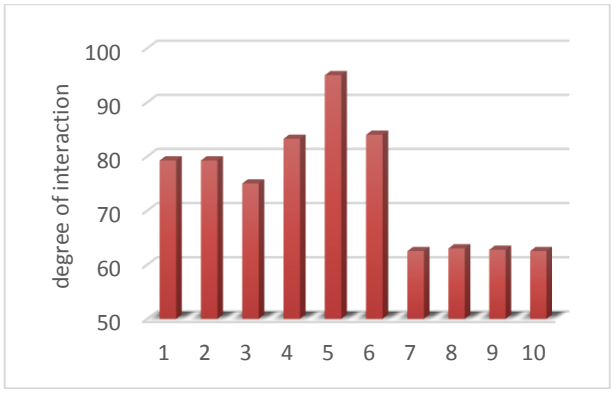

Figure 8. Floor samples

- The results showed that sample (15) -drons- which uses digital interactive techniques is higher in the interactive value (87.5) than other ceiling, while sample (14) - Reflective Boxes - which uses traditional interactive techniques, got the lowest degree of interactivity (56.25) as shown in figure 9.

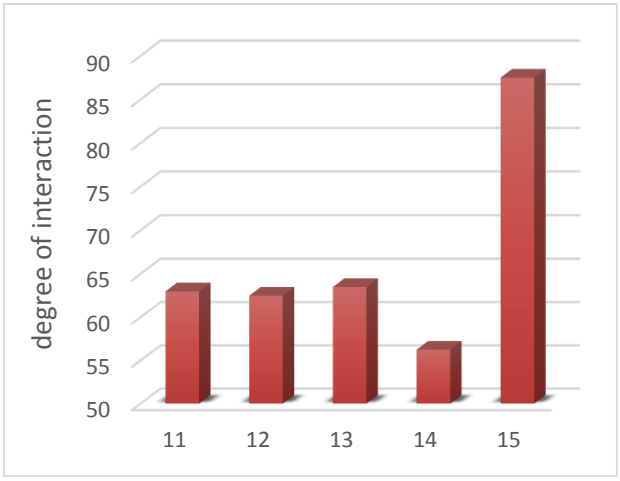

Figure 9. Ceiling samples

- The results showed that samples (20 and 21) are higher in the interactive value (95.25) than other walls, while sample (19), which uses traditional interactive techniques, got the lowest degree of interactivity (56.25) as shown in figure 10.

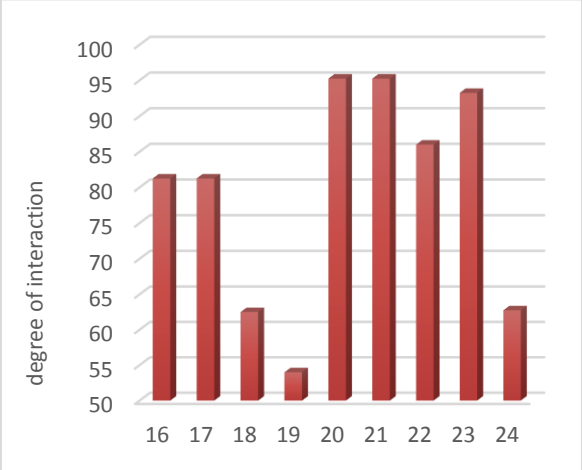

Figure 10. Wall samples

- The results showed that samples (47) – interactive screen- is higher in the interactive value (96) than other furniture, while sample (31) got the lowest degree of interactivity (52). The results also proved the existence of a large variance between furniture samples, ranged from (52-96) as shown in figure 11.

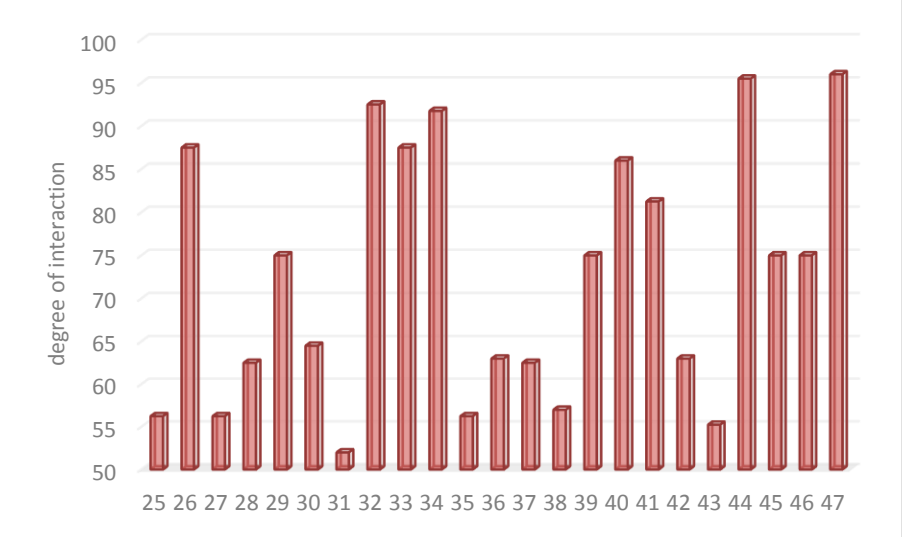

Figure 11. Furniture samples

6. Checking the efficiency of the result of the fuzzy inference system

Statistical tests were used to ensure the accuracy of the results of the fuzzy system in calculating the degree of interaction of outer spaces designs. Simple linear regression was used to find out the extent of the influence of the independent variables on the dependent variable (the degree of interactivity). The results proved that all the variables are significant, except for the third variable (the function of interactive ideas), which is

not significant because the P-Value for this variable is greater than 0.05, so it was neglected. The results also proved that the second variable (the effect of ideas on the recipient) is the most influential variable on the degree of interactivity because the t-value is 6.45 and the SE coefficient error value is the least and is equal to 0.4688, followed by the first variable with a t-value of 4.9 and SE coefficient error value of 0.7, then the fifth variable with a t-value of 2.14 and SE coefficient error value of 0.9, then, finally, the fourth variable with t-value of 1.93 and its SE coefficient error value is the highest and equals 1.722.

- The fuzzy inference system model is an efficient model for calculating the degree of interactivity, as the value of R-Sq(adj) = 83
- The top 3 standard errors in the data did not exceed ± 2.5 and therefore they are not considered abnormal values.
- The statistical T-test was used and it was found that there is a significant difference between the designs that adopt digital technologies and those adopting traditional techniques.

Thus, we assume that:

- H0: There is no significant difference between the two samples (M1=M2)).
- H1: There is a significant difference (M1≠M2)
- After applying the test, it became clear that there is a significant difference between the two methods used in the design, thus rejecting the null hypothesis (H0) and accepting the alternative hypothesis (H1) based on the values resulting from the statistical analysis process, as the value of SIG.(2-TAILED) = 0.00 which is less than 0.05.
- We conclude from this, that the methods adopting digital technologies achieve higher interactivity compared with traditional technologies; This is because the rate of digital technologies (Mean) equals 82.5100, which is greater than the rate of traditional technologies (Mean) which equals 64.7300.

7. Conclusions

This study sheds light on the problem of evaluating interaction in outdoor spaces designs. As more and more designs of outdoor spaces become dead and ineffective, it was necessary to find ways to increase interaction between them and people, and to find out which of these methods is the best through a numerical value, thus a Fuzzy Inference System was proposed to measure the degree of interactivity for fifty global samples of outer space, based on five features extracted from previous study, accordingly we find that the use of the Fuzzy inference system gives reliable results when used in calculating the degree of interaction of architectural projects in outdoor spaces. The study has been concluded that the reason of digital technologies offers interactive capabilities more than traditional technologies because they often use more than one technology together, up to seven technologies instead of two or three only in traditional technology. Also, digital technology has a greater impact on the users. Finally, the results proved that the second Feature (the influence of ideas on user) is the most influential in the degree of interactive in external designs.

References

Abazov, R. (2015). 5 Ways to Improve Your Creative Thinking. Retrieved on 13/09/2020, from URL: https://www.topuniversities.com/blog/5-ways-improve-your-creative-thinking

Abdel-Aziz, A.A., Abdel-Salam, H., & El-Sayad, Z. (2016). The role of ICTs in creating the new social public place of the digital era. *Alexandria Engineering Journal*, *55*(1), 487-493.

Ahmed, M., Mohamed, E., & Shata, E. (2018). Non-electronic interactive methods and their role in the interactive advertising design. *Journal of Architecture, Arts and Humanistic Science*, *3*(11(2)), 612-633.

Alfano, M. (2004). Peace Offering (Functional Bench). Retrieved on 20/08/2020, from URL: https://www.michaelalfano.com/tag/interactive/?id=823

Ali, D.A.A.R. (2013). The effect of artificial lighting in the nightscape figuration of the landscape. University of Technology Baghdad.

Azzarello, N. (2014). Miguel Chevalier projects digital arabesques along the Al Majaz waterfront. Retrieved on 13/09/2020, from URL: https://www.designboom.com/art/digital-arabesquesmiguel-chevalier-islamic-art-festival-01-10-2015

Bloom, J. (2016). Musical Swings: An exercise in collaboration. Retrieved on 10/09/2020 from URL: https://www.dailytouslesjours.com/en/work/musical-swings

Booth, N. (2011). *Foundations of landscape architecture: integrating form and space using the language of site design*. John Wiley & Sons.

Bored Panda, T. (2012). Artificial Urban Glaciers in Enschede. Retrieved on 12/09/2020 from URL: https://www.boredpanda.com/roombeek-brook-urban-glaciers/?utm_source=pinterest&utm_medium=social&utm_campaign

Britannica, The Editors of Encyclopaedia. Montreal Botanical Garden. Encyclopedia Britannica, 1 Sep. 2017, https://www.britannica.com/place/Montreal-Botanical-Garden. Accessed 30 November 2022.

Brown, C. (2012). Cloud made from 6,000 light bulbs by caitlind brown. Retrieved on 10/11/2020 from URL: https://www.designboom.com/design/cloud-made-from-6000-light-bulbs-by-caitlind-brown/

Bruder, K.A., Ucok, O. (2000). Interactive art interpretation: How viewers make sense of paintings in conversation. *Symbolic Interaction, 23*(4), 337-358.

Bruges, J. (2013). Interactive Artwork Will Turn Your Shadow in to An Animation. Retrieved on 12/08/2020 from URL: https://www.vice.com/en/article/4xqg3b/artwork-will-turn-your-shadow-into-an-animation

Cani, M.-P., Igarashi T. et al. (2008). Interactive Shape Design. *Synthesis Lectures on Computer Graphics and Animation, 3*(1), 1-78.

CGTN. (2021). Retrieved on 03/01/2021 from URL: https://arabic.cgtn.com/n/BfJEA-EA-BIA/FBAIEA/index.html

CGTN. (2021). Retrieved on 07/02/2021 from URL: https://arabic.cgtn.com/n/BfJEA-EA GAA/FCd BIA/index.html

Caboz, J. (2018). These are some of our favourite statues of Nelson Mandela from around the world. Retrieved on 25/10/2020 from URL: https://www.businessinsider.co.za/amp/these-are-some-of-our-favourite-statues-of-nelson-mandela-2018-12

Company, P. (2016). Music Made for The Great Outdoors. Retrieved on 11/09/2020 from URL: https://www.percussionplay.com/

Coombs, D.B.-M., Cracknell, P., Bentley, R. (2001). *The Complete Book of Pruning*. Sterling Publishing Company,

Damoda, S. (2020). The Navigator of Formation Drone Light Show. Retrieved on 01/01/2021 From URL: http://en.dmduav.com/list-17.html

Dekel, A., Simon, Y., Dar, H., Tarazi, E., Rabinowitz, O., & Sterman, Y. (2005, November). Adding playful interaction to public spaces. In *International Conference on Intelligent Technologies for Interactive Entertainment* (pp. 225-229). Springer, Berlin, Heidelberg.

Deutscher, K.B. (2014). Urban Reef wins Robson Redux 2014 in downtown Vancouver, Canada. Retrieved on on 18/09/2020 from URL: https://bustler.net/news/39/urban-reef-wins-robson-redux-2014-in-downtown-vancouver-canada .

Dodge, J. (2015). Climbing Walls at Maggie Daley Park Officially Open. Retrieved on 04/11/2020 from URL: https://chicago.cbslocal.com/2015/05/12/climbing-walls-at-maggie-daley-parkofficially-open

Dombrowski, J. (2012). Dubai Fountain. Retrieved on 20/4/2020 from URL: https://luxeadventuretraveler.com/dancing-dubai-fountain/

Elesapiens (2018). Bright ideas for a different school playground. Retrieved on 03/06/2020 from URL: https://www.elesapiens.com/blog/bright-ideas-for-a-different-school-playground/

Enas Salem, R.M.M. (2013). Interactive architectural design. *Engineering and Technology*, 6.

EPA. (2016). The floor is lava, and other optical illusion artworks pop up in South Korea. Retrieved on 10/09 /2020 from URL: https://www.bostonglobe.com/news/world/2016/10/27/the-floor-lava-and-other-optical-illusion-artworks-pop-south-korea/qtkbY3qRDSBLdfG6Wyj1JJ/story.html

Erman, M. (2018). A recreational pavilion with huge hammocks in Dubai. Retrieved on 18/9/2020 from URL: https://www.designboom.com/architecture/pinkcloud-dk-dubai-smiles-01-31-2018/

Erman, M. (2018). ”nituniyo + memosesmas' installation is a blank canvas inviting visitors to express themselves”. Retrieved on 31 /7 /2020 from URL: https://www.designboom.Com/art/nituniyomemosesmas-installation-blank-canvas-visitors-express-themselves07-23-2018/

Ervin, S.M. (2018). Sensor-y Landscapes: Sensors and Sensations in Interactive Cybernetic Landscapes. *Journal of Digital Landscape Architecture*, 96-106.

FGTeam (2016). Sensigom Delivers Versatile Range of Interactive Solutions for Indoor and Outdoor Play. Retrieved on 03/06/2020 from URL: https://www.fitness-gaming.com/news/schools/sensigom-delivers-versatile-range-of-interactive-solutions-for-indoor -and-outdoor-play.html

Frearson, A. (2011). Lisbon Christmas Lights by Pedro Sottomayor, José Adrião and ADOC. Retrieved on 08/09/2020 from URL: https://www.dezeen.com/2011/12/23/lisbon-christmas-lightsby-pedro-sottomayor-jose-adriao-

Frearson, A. (2013). Dalston House by Leandro Erlich. Retrieved on 08/09/2020 from URL: https://www.dezeen.com/2013/06/26/dalston-house-by-leandro-erlich/

Giannetto, J. (2019). 10 things you shouldn’t miss at Chicago’s Millennium Park Campus. Retrieved from URL: https://www.choosechicago.com/blog/arts-culture-entertainment/10-things-you-shouldnt-miss-at-chicagos-millennium-park-campus /

Grønbæk K., Kortbek K.J., Møller C., Nielsen J., Stenfeldt L. (2012). Designing Playful Interactive Installations for Urban Environments – The SwingScape Experience. In: Nijholt A., Romão T., Reidsma D. (eds) *Advances in Computer Entertainment*. ACE 2012. Lecture Notes in Computer Science, vol 7624. Springer, Berlin, Heidelberg, pp. 230-245.

Guido, G. (2019). Theory of Time, the installation revealed by its own shadow. Retrieved on 20/09/2020 from https://URL:https://www.collater.al/en/theory-of-time-daku-installation/

Gunes, H., & Piccardi, M. (2005, October). Affect recognition from face and body: early fusion vs. late fusion. In *2005 IEEE international conference on systems, man and cybernetics* (Vol. 4, pp. 3437-3443). IEEE.

Guo, Y., Du, Q., Luo, Y., Zhang, W., & Xu, L. (2008). Application of augmented reality GIS in architecture. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 37, 331-336.

Hamed, H. (2017). Animated fountain in China. Retrieved on 12 2020/12/ from URL: https://www.elmydannews.com/news/14482/29-6-2017

Howard, H. (2019). More than a hundred drones put on a mesmerising light show over Lake Zurich as part of the city's triennial Züri Fäscht festival. Retrieved from on 15/07/2020 URL: https://www.dailymail.co.uk/news/article-7219123/Drones-light-night-sky-incredible-display-Lake-Zurich-Z-ri-F-scht-festival.html

Howarth, D. (2014). Les Astronautes fills Quebec passageway with swimming pool toys. Retrieved on 20/09/2020 from URL: https://www.dezeen.com/2014/10/13/les-astronautes-delirious-frites-pool-noodles-installation-quebec/

Huo, S. (2016). Interactive landscape Rhoda Island school of design. Master Thesis, Department of Landscape Architecture of the Rhode Island School of Design.

Johnson, P. (2011). Stringy Yellow Tube Playscape Blanton Museum of Art, Houston Texas Retrieved on 08/11/2020 From URL:http://www.play-scapes.com/play-art/playable-sculpture/stringy-yellow-tube-playscape-blanton-museum-of-art-houston-texas/

Jordahn, S. (2017). Pavegen's floor tiles could power future cities with footsteps. Retrieved on 10/09/2020 from URL: https://www.dezeen.com/2017/10/27/movie-mini-living-pavegen-flooring-system-power-future-smart-cities-video/

Karaarslan, S. V. (2018). Application of augmented reality technologies in archaeology. *English Artic*, 2018, 181-200.

Karino, A., Osugi, T., Kimura, Y., & Takami, T. (2012, October). Development of exertainment with interactive floor display. In *The 1st IEEE Global Conference on Consumer Electronics* 2012 (pp. 99-100). IEEE.

King, J. (2013). Song, dance and light in Southampton as artwork sends Guildhall square aglow. Retrieved on 05/11/2020 URL: https://www.culture24.org.uk/art/art457502

Kostrenčić-Krebel. (2013). Petar Zoranić Square and Šime Budinić Plaza / Kostrenčić-Krebel. Retrieved on 10/07/2020 from URL: https://www.archdaily.com/478606/petar-zoranic-square-and-sime-budinic-plaza-kostrencic-krebel?ad_medium=gallery

Lafitte, B. (2019). The 5 best interactive wall (Digital Signage) examples made with Intuiface. Retrieved on 30/04/2020 from URL: https://www.intuiface.com/blog/5-best-interactive-wall-examples

Li, J.F., & Ding, M.J. (2014). Research of Landscape Interactive Design. In *Advanced Materials Research* (Vol. 1051, pp. 791-796). Trans Tech Publications Ltd.

Lusiardi, F. (2016). Denmark | The Art Playground of the Ordrupgaard museum. Retrieved on 12/03/2020 from URL: http://www.inexhibit.com/marker/denmark-the-art-playground-ofthe-ordrupgaard-museum/

Lutyens, D. (2020). Five stunning outdoor spaces for all. Retrieved on 03/11/2020 from URL: https://www.bbc.com/culture/article/20200602-five-stunning-outdoor-spaces-for-all?ocid=fbcul

MacLeod, F. (2014). Get Swinging in Boston on these Glowing LED Hoops. Retrieved on 30/06/2020 from URL: https://www.archdaily.com/549643/get-swinging-in-boston-on-these-glowing-led-hoops?ad_medium=gallery

Najafi, E., Faizi, M., & Khanmohammadi, M.A. (2020). Biological inspiration in architectural design: reviewing the influence of the living world on architectural theory and practice. *Journal of Building Performance, 11*(1).

Neira, J. (2015). City yeast creates anemone-like scene with 1000-cylinder balloons in Taipei. Retrieved on 04/10/2020 from URL: https:// www.designboom.com/design/city-yeast-balloonsinstallation-taipei-12-09-2015/

Ong, Z. (2017). NIKE's unlimited stadium in manila is the 'world's first LED running track'. Retrieved on 8/11 /2020 from URL: https://www.designboom.com/design/nike-unlimited-stadium-manila-worlds-first-led-running-track-05-08-2017/

Paradise, S.O. (2019). Canadian Content on the Happy Wall. Retrieved on 05/09/2020 from URL: https://snowbirdofparadise.com/2019/05/22/canadian-content-on-the-happy-wall/

Proulx, C.L. (2020). A Large-Scale Public Art Mural That Appears to Warp The Street. Retrieved on 04/12/2020 from URL: https://www.contemporist.com/public-art-mural-appears-to-warp-thestreet/

Ritter, D. (2000). My Finger's Getting Tired: Interactive Installations for the Mind and Body'. Electronic Art and Animation Catalog.

Roosegaarde, D. (2014). Marbles of light. Retrieved on 17/09/2020 from URL: https://www.designindaba.com/articles/creative-work/marbles-light

Rosenfield, K. (2016). Janet Echelman Suspends Net Sculpture Over London's Oxford Circus. Retrieved on 20/09/2020 URL: https://www.archdaily.com/780408/janet-echelman-suspends-net-sculpture-over-londons-oxford-circus

Saraceni, R. (2018). Big Piano. Retrieved on 29/07/2020 from URL: https://redlandsdistribution.com/big-piano/

Schnabel, M.A., Karakiewicz, J. (2007). Rethinking parameters in urban design. *International Journal of Architectural Computing, 5*(1), 83-98.

Serrat, O. (2017). *The Scamper technique*. *Knowledge Solutions*, Springer, 311-314.

Skitek, R.R. (2014). Paprocany Lake Shore Redevelopment / RS + Robert Skitek. Retrieved on 10/05/2020 from URL: https://www.archdaily.com/775301/paprocany-lake-shore-redevelopment-rs-plus

Smithe, A. (2017). Artwork of the week: les voyageurs. Retrieved on 08/09/2020 from URL: https://the8percent.com/artwork-of-the-week-les-voyageurs/

Song, J., Huang, S. (2018). Virtual Reality (VR) Technology and Landscape Architecture. In *MATEC Web of Conferences* (Vol. 227, p. 02005). EDP Sciences.

Stewart, J. (2017). Rainbow Labyrinth Light Installation Immerses Visitors in a Technicolor World. Retrieved on 06/01/2020 from URL: https://mymodernmet.com/brut-deluxe-light-installationrainbow-labyrinth/

Stewart, J. (2019). Giant Mirror Installation Invites the Public to Step Inside a Kaleidoscope of Color. Retrieved on 16/10/2020 from URL: https://mymodernmet.com/softlab-alexandria-public-art/

Tamir, D.E., Rishe, N.D., & Kandel, A. (2015). Complex fuzzy sets and complex fuzzy logic an overview of theory and applications. *Fifty years of fuzzy logic and its applications*, 661-681.

Thomas, B. (2017). 5 Augmented Reality Campaigns That Actually Worked, Retrieved on 20/11/2020 from URL: https://madebymoment.com/5-augmented-reality-campaigns-actually-worked/

Ya-Ling, H., Yang, I., & Fan, H. (2016, May). Time context traveling with hologram projection a case study of Tainan historical monument. In *2016 International Conference on Applied System Innovation* (ICASI) (pp. 1-4). IEEE.

Yoo, A. (2011). Giant Moving Head Steel Sculpture by David Cerny. Retrieved on 05/09/2020 from URL: https://mymodernmet.com/giant-moving-head-steel-sculpture/

Yoo, A. (2012). Color Changing Bubbles Tell Stories Through Shadows. Retrieved on 07/08/2020 from URL: https://mymodernmet.com/media-lucion-shadow-balls/

Yoo, A. (2013). Maze of Mirrors Mesmerizes Visitors Inside Sydney's Hyde Park. Retrieved from URL: https://mymodernmet.com/art-and-about-sydney-field/

Zadeh, L.A. (1965). Fuzzy sets. *Information and control*, *8*(3), 338-353.