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Fuzzy Logic Approach to Social Media Marketing: Distribution of Advertising Budget According to Different Age Groups and Genders

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Abstract

In this study, the effect of fuzzy logic approach in social media marketing on the distribution of advertising budgets according to different age groups and genders was examined. The findings show that the fuzzy logic method can be used effectively in advertising budget distribution. The usage rates of five main social media platforms such as Facebook, Instagram, X (Twitter), YouTube and LinkedIn were imported into MATLAB for analysis. The data obtained with the MATLAB program, which uses fuzzy logic algorithms, helps to distribute the advertising budget more evenly and efficiently by considering complex variables such as age and gender. The results highlight that the fuzzy logic approach can be used as an important tool in developing segmentation and targeting strategies in social media marketing. This study reveals the applicability of fuzzy logic techniques to increase efficiency and gain competitive advantage in social media advertising.

Keywords: fuzzy logic, social media marketing, digital marketing, MATLAB

1. Introduction

Fuzzy logic is a mathematical framework that addresses situations characterized by uncertainty and imprecision. It facilitates the modeling and analysis of systems by incorporating concepts that lack distinct boundaries. This approach enables computers to make decisions akin to human reasoning, providing a direct method for deriving definitive conclusions from vague, noisy, or incomplete input data. Fuzzy logic recognizes both accurate and inaccurate values, reflecting its flexibility in handling ambiguous information (Raja & Ramathilagam 2021).

Since fuzzy logic is a mathematical approach that deals with uncertainty and imprecise information, this makes it suitable for a variety of applications, including social media marketing. Fuzzy logic is used in many different fields. For example, fuzzy logic is effective in complex decision-making processes by using it in artificial intelligence and robotic systems (Skansi, 2018). Fuzzy logic is a mathematical paradigm that contends with scenarios marked by uncertainty and imprecision. It enables the modeling and examination of systems by incorporating concepts devoid of precise boundaries. Fuzzy logic acknowledges both accurate and inaccurate values, exemplifying its adaptability in managing ambiguous information.

In contemporary business environments, digital marketing has become an essential tool for organizations to effectively reach their target audiences and enhance brand recognition. Social media platforms represent a fundamental component of digital marketing strategies, given their capacity to engage with expansive audiences. The ability to meticulously target specific demographic segments, such as age groups and gender, has become a defining feature of social media advertising. However, when creating social media marketing strategies for companies, how to distribute the advertising budget is an important problem. In recent years, social media has revolutionized the way businesses approach marketing and advertising. Companies: They have realized the potential to reach their target audience more effectively and efficiently through social media advertising through platforms with billions of active users such as YouTube, Facebook, X (Twitter), and Instagram. Furthermore, ad spending in the social media advertising market is projected to reach USD 219.8 billion in 2024. In the social media advertising market, the number of users is expected to reach 6 054 million users by 2028 (Statista, 2024). This growth in social media advertising has led companies to allocate a larger portion of their advertising budgets to social media marketing.

The use of fuzzy logic in social media marketing is a promising approach that offers various benefits such as improved targeting, personalization and risk management (De-Arteaga, Feuerriegel, & Saar-Tsechansky, 2022). Moreover, the use of fuzzy logic in social media marketing is expected to have significant implications for the future. However, despite all these positive thoughts, there are some opposing views and potential challenges to be considered. For example, some researchers argue that the inherent complexity and subjectivity of fuzzy logic may be difficult to apply and validate in real-world marketing activities. These researchers are concerned that relying on fuzzy logic for subjective human evaluations may lead to inconsistencies in decision-making. (Bright & Logan, 2018). In addition, when fuzzy logic is not fully compatible with existing marketing analytics and decision-making frameworks, it can lead to some technical and organizational difficulties. On the other hand, some marketers may also be skeptical about adopting fuzzy logic, arguing that traditional, data-driven approaches are more trustworthy and transparent (Zou, Jun & Bai, 2021). When fuzzy logic models are complex and hard to understand, it is difficult for them to be accepted by the masses (Sharma et al., 2021). Fuzzy Logic models can often be complex and difficult to understand, making them difficult to accept by the masses (Adams & Hagras, 2020). Furthermore, the scalability of fuzzy logic systems is another major concern. Because as the number of inputs increases, the number of required rule sets increases

exponentially. This, in turn, makes it difficult to maintain and expand the system (Singh, et al., 2013). On the other hand, fuzzy logic, despite its success in managing uncertainty, is criticized for sometimes producing inconclusive results. This can be particularly problematic in areas that require high precision (Kalibatienė, Miliauskaitė, Dzemydienė & Maskeliūnas, 2020). Developing an effective fuzzy logic model is often dependent on expert knowledge. This can increase potential biases to the model (Gupta, 2021). As a result, these limitations stand out as important factors limiting the wide adoption and application of fuzzy logic.

Despite all these concerns, the potential benefits of fuzzy logic in social media marketing, such as improved targeting, personalization, and risk management, suggest that more research and practical application is necessary to comprehensively assess its effectiveness and address all limitations. In this context, the fuzzy logic approach in social media marketing can become a valuable tool when it comes to distributing advertising budget to different demographic groups. By considering factors such as age and gender, the fuzzy logic model can help marketers better target their advertising messages to specific demographics. As a result, the use of fuzzy logic in social media marketing will ensure that advertising budgets are allocated more accurately and precisely according to different age groups and gender.

The purpose of this article is to analyze social media usage habits and ad interactions among users of different age groups and genders and to develop a model that will ensure an optimal distribution of advertising budget using fuzzy logic methods. This study aims to help businesses make their social media marketing strategies more effective and efficient.

2. Literature Review

Lofti A. Zadeh (1965) is the founder of fuzzy logic. Zadeh laid the foundations of fuzzy logic and fuzzy sets by introducing the concept of fuzzy logic theory in his 1965 paper (Seising, 2015). Over time, fuzzy logic has evolved and has found widespread application in various fields, including control systems, artificial intelligence, medical diagnosis, natural language processing, and the Internet of Things (Harahap, Suwilo & Sembiring, 2021).

Table 1. Historical development of fuzzy control

Year	Implemented by	Field of application
1972	Zadeh	Proposing Fuzzy Control
1974	Mamdani and Assilian	Steam engine control
1977	Willaeys	Optimal fuzzy control
1980	F. Mizumoto and Tanaka	Fuzzy condition inference
1984	Sageno and Murakabi	Parking control of a car
1985	Kiszka and Gupta	Stability of the fuzzy system
1986	Yamakawa	Fuzzy Controller system
1988	Dubois and Parade	Approximate reasoning

According to Ödük (2019), the historical development of fuzzy logic is shown in Table 1.

3. Results

3.1 Purpose and Scope

The purpose of this paper is to use a fuzzy logic approach in social media marketing to examine the allocation of advertising budgets by age and gender. In the context of the rapidly growing and diversifying world of social media platforms, it is critical to identify the most effective advertising strategies and allocate the budget accordingly. In this context, by analyzing the usage rates of five major social media platforms, namely Facebook, Instagram, X (Twitter), YouTube and LinkedIn, the effectiveness of different social media strategies will be evaluated. The methodology of the study is based on the selection of platforms based on two main sources of information: "Selected Social Media Platforms and Reasons" along with "Selection Criteria". A clear understanding of the basic principles of the research is provided by explaining which platforms were selected and why, and what the selection criteria were. This study highlights the use of a fuzzy logic approach in the field of social media marketing and its potential implications for the development of advertising strategies for different demographic groups. In this way, the aim of the paper is the provision of a new perspective in the field of social media marketing.

3.2 Method

Within the scope of this research, five major and well-known social media platforms such as Facebook, Instagram, X (Twitter), YouTube, LinkedIn were selected to examine the allocation of advertising budget according to different age groups and genders using fuzzy logic approach in social media marketing. Five major and well-known social media platforms, including Facebook, Instagram, X (Twitter), YouTube, and LinkedIn, were discussed. Factors such as user base, advertising options, interaction features, nature of the platform and timeliness were considered in the selection of these social media platforms. The main reason for choosing Facebook is that it provides access to a large user base and has detailed targeting options. The rationale behind Instagram's preference is its focus on visual content and its popularity, especially among young users. X (Twitter) was chosen because it allows news to spread quickly and because of its interactive nature. YouTube was chosen mainly because it allows for the effective dissemination of video content and has a wide range of advertising options. Finally, LinkedIn was chosen because of its professional user base and its hosting of business-oriented content. These choices were made in line with the objectives of the research and strategies to reach specific demographic groups.

Table 2. The percentage of individuals utilizing social media platforms globally

	YouTube		Facebook		X (Twitter)		Instagram		LinkedIn	
Age groups	Women	Man	Women	Man	Women	Man	Women	Man	Women	Man
18-24	8,7	16	5,7	8,7	8,6	20,3	7,6	10,9	7	9,4
25-34	11,4	18	13	15	9,9	19,7	15	16,3	15,6	18,5
35-44	8	11	9,9	10,6	6,3	11,6	10	10,5	9,4	9,9
45-54	5,4	8	7,8	8,4	4,1	7,3	6,9	7,3	7,2	7,8
55-64	3,6	5	6,2	7	2,7	4,7	4,8	5,7	4,6	5,1
65 +	2,1	3	3,5	4,2	1,6	3,2	2,1	2,9	2,5	3

Table 2 shows the global usage of Facebook, Instagram, X (Twitter), YouTube and LinkedIn according to Statista (2024). The usage rates of social media platforms were normalized into percentages to determine each platform's share of the total usage. These normalized percentages were then transferred to the MATLAB program. The data obtained with the MATLAB program using fuzzy logic algorithms facilitated advertising budget optimization among different age groups and genders. Fuzzy logic models in MATLAB enabled a more balanced allocation of the advertising budget by considering complex variables such as age and gender. This method allows marketing strategies to be more effective and more relevant to the target audience.

"Input" parameters are required for companies to optimally adjust the advertising budget according to social media platforms using fuzzy logic. The input parameters in the model are "Gender of the target customer" and "Age group of the target customer". The fuzzy logic controller processes these input parameters and produces "output" accordingly. This output is very important; "What percentage of the advertising budget will be used in which social media channel. (YouTube, Facebook, Instagram, X (Twitter), and LinkedIn).”

To address the intricacies of the fuzzy logic controller, the input and output values are pre-determined. The crisp input values are then mapped to fuzzy values through the application of a membership function, which is subsequently subjected to an appropriate processing stage. This conversion of the crisp value into a fuzzy value is referred to as "fuzzification" (Raja & Ramathilagam, 2021).

3.3 Limitations

Fuzzy Logic was introduced by Zadeh in 1965 and over the years, it has been applied in various fields such as control systems, artificial intelligence, medical diagnosis, natural language processing, and the internet of things (Harahap, et al., 2021). However, despite its wide range of applications, fuzzy logic has some important limitations.

Fuzzy logic models are often complex and can be difficult to understand. This can make it

difficult for them to be adopted by a wide range of users. Complexity can also make it difficult to correctly apply the models and interpret their results. Therefore, making fuzzy logic models more understandable and user-friendly is an important research topic.

As the number of input variables increases, the number of required rule sets also increases exponentially. This complicates the scalability of fuzzy logic systems and can hinder fast processing in real-time applications (Khan, 2024). Especially for large data sets and dynamic environments, this can become a major constraint. Scalability issues can limit the use of Fuzzy Logic in large-scale and complex systems. Therefore, solutions to increase the scalability of fuzzy logic models are among the priority topics of the research agenda.

While fuzzy logic is successful at managing uncertainty, it can sometimes produce imprecise results. This can be particularly problematic in areas that require high accuracy (Kalibatienė et al., 2020). For example, in medical diagnostics or automation systems, these uncertainties can have unacceptable consequences. These limitations in precision and accuracy may result in fuzzy logic not being preferred in some critical application areas. In this regard, it is necessary to develop methods to increase the accuracy and precision of fuzzy logic.

Developing effective fuzzy logic systems often relies on expert knowledge. Since the definition of rules and membership functions depends on the opinions of experts, this can add subjective elements and potential biases to the model (Gupta, 2021). This dependency can reduce the reliability and objectivity of the model. This reliance on expert knowledge can also slow down the development of the model and make it costly. Therefore, it is important to use more objective and data-driven methods in the development of fuzzy logic models.

This study aims to find a way forward for the use of fuzzy logic in social media marketing by considering the limitations given above and applying various strategies against them. A more manageable number of social media platforms were selected, focusing on specific main demographic variables (age and gender) to simplify the fuzzy logic models used in the study. This approach makes the rule set and membership functions understandable and manageable, allowing marketing professionals to easily understand and implement results. This makes it easier for fuzzy logic models to be user-friendly and widely adopted.

MATLAB's fuzzy logic toolbox has been used to address scalability issues. This toolbox optimized the handling of fuzzy logic systems, enabling it to manage multiple input variables and complex rule sets more easily and efficiently. This allows for the effective use of fuzzy logic in large data sets and dynamic social media environments. Furthermore, this toolbox enables models to work quickly and accurately, increasing their usability in real-time applications.

One of the goals of this study is to minimize the fuzziness problem by using precise input data and validating fuzzy logic models against real-world social media usage patterns. The purpose of this validation step is to ensure that the models provide reliable and actionable insights for advertising budget allocation. These validations with precise data increase the accuracy of fuzzy logic models and improve the effectiveness of marketing strategies. This makes fuzzy logic especially preferred in applications that require high accuracy.

A data-driven approach has been adopted to define rules and membership functions to reduce reliance on expert knowledge. Potential biases have been reduced by using statistical analysis and machine learning techniques. Thus, the objectivity and reliability of fuzzy logic models increased. This data-driven approach allows models to be more objective and unbiased, increasing the effectiveness and accuracy of marketing strategies. In addition, this method accelerates the development process of models and reduces costs

3.4 Rules

The decisions made by the fuzzy logic controller are derived from rule sets called fuzzy rules. In this study, 18 rules were created. As an example, three of them are analyzed in terms of the following "IF" and "THEN" statements:

Rule 1. If (age_groups is 18-24) and (Sex is Women) then (Youtube_-_Women is 18-24)(Facebook_-_Women is 18-24)(X_(Twitter)_-_Women is 18-24)(Instagram_-_Women is 18-24)(Linkedin_-_Women is 18-24)

Rule 2. If (age_groups is 25-34) and (Sex is Women) then (Youtube_-_Women is 25-34)(Facebook_-_Women is 25-34)(X_(Twitter)_-_Women is 25-34)(Instagram_-_Women is 25-34)(Linkedin_-_Women is 25-34)

……

Rule 9. If (age_groups is 35-44) and (Sex is Man) then (Youtube_-_Man is 35-44)(Facebook_-_Man is 35-44)(X_(Twitter)_-_Man is 35-44)(Instagram_-_Man is 35-44)(Linkedin_-_Man is 35-44)

……

Rule 18. If (age_groups is 65+) and (Sex is Unisex) then (Youtube_-_Unisex is 65+)(Facebook_-_Unisex is 65+)(X_(Twitter)_-_Unisex is 65+)(Instagram_-_Unisex is 65+)(Linkedin_-_Unisex is 65+)

Fuzzification is used to use the results of a fuzzy inference engine to obtain a result, such as the impact on the allocation of advertising budget by age groups in social media marketing. Here, defuzzification is used to transform the membership degrees of fuzzy sets into a specific real value. This process is usually performed by the centroid method (Raja & Ramathilagam, 2021).

Table 3. Example of rule set used in MATLAB

Rule number	Linguistic inputs		Linguistic outputs				
	Sex	Age Groups	Social Media Platforms by Age Groups (%)				
1	Women	18-24	18-24 YouTube %	18-24 Facebook %	18-24 X (Twitter) %	18-24 Instagram %	18-24 LinkedIn %
9	Man	35-44	35-44 YouTube %	35-44 Facebook %	35-44 X (Twitter) %	35-44 Instagram %	35-44 LinkedIn %
18	Unisex	65+	64+ YouTube %	65+ Facebook %	65+ X (Twitter) %	65+ Instagram %	65+ LinkedIn %

The set of rules utilized in MATLAB to elucidate the impact of social media marketing on the distribution of advertising budgets by age groups is presented in Table 3.

3.5 Simulation and Results

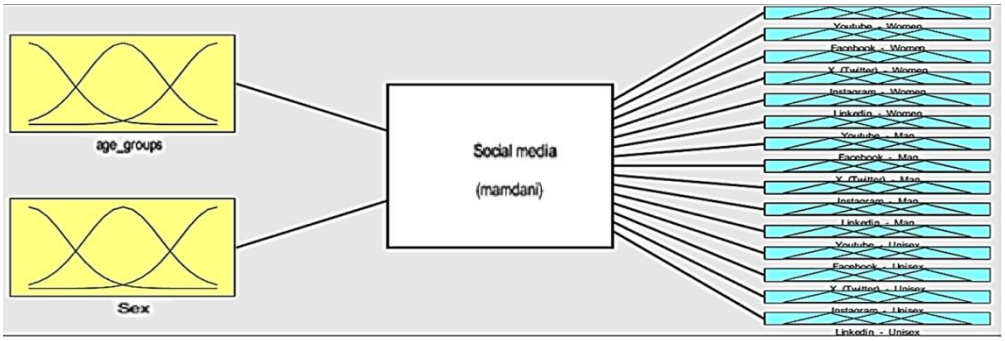

Figure 1. Fuzzy logic controller for social media

Figure 1 depicts the "Fuzzy Logic Controller" utilized in this study. It comprises two inputs and 15 outputs. The FIS Type is "mamdani." In all inputs and outputs in this study, "pimf" was employed as the current membership function type.

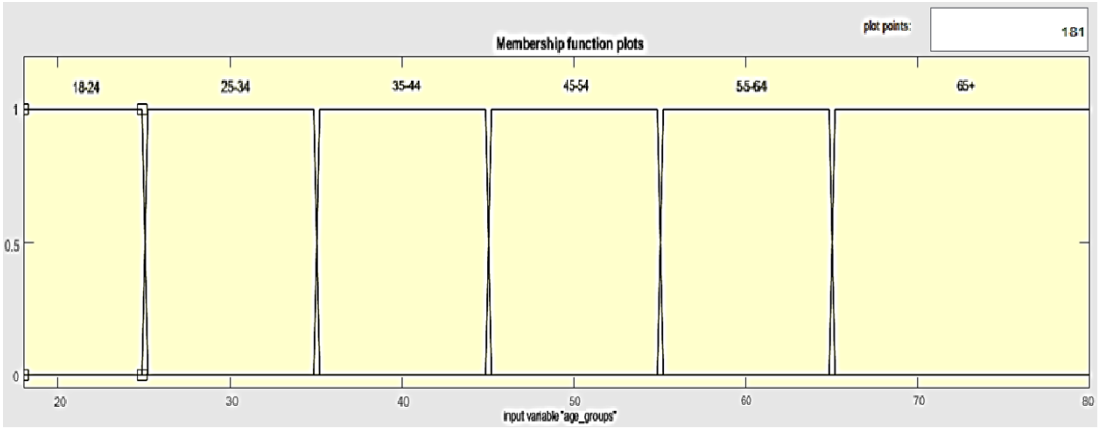

Figure 2. Membership function plot for age groups

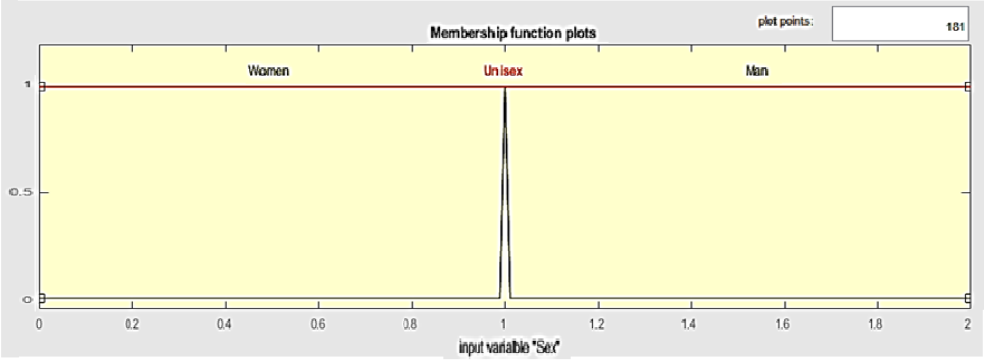

Figure 3. Membership function plot for sex

In Figures 4, 5, 6, 7, 5, and 9, sample outputs of the "Current Membership Function" are provided.

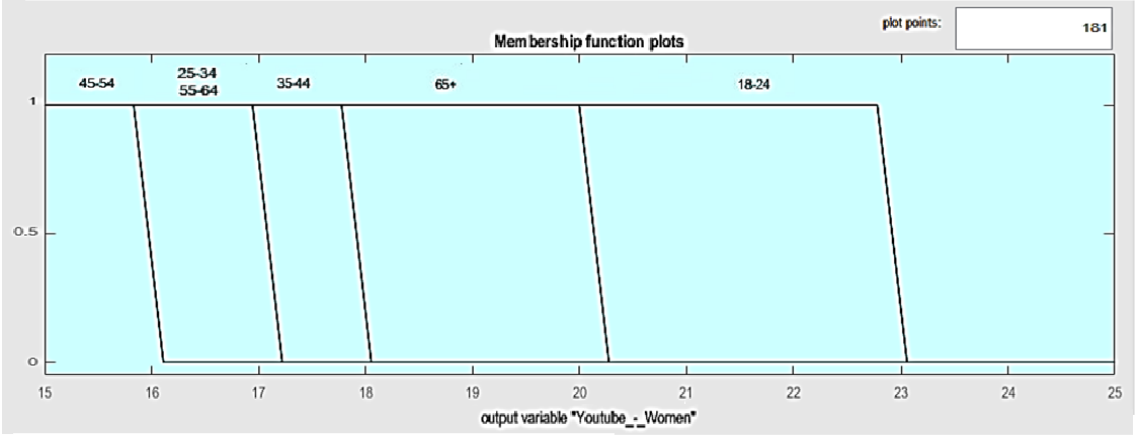

Figure 4. The graph of the current membership function for "Youtube – Women"

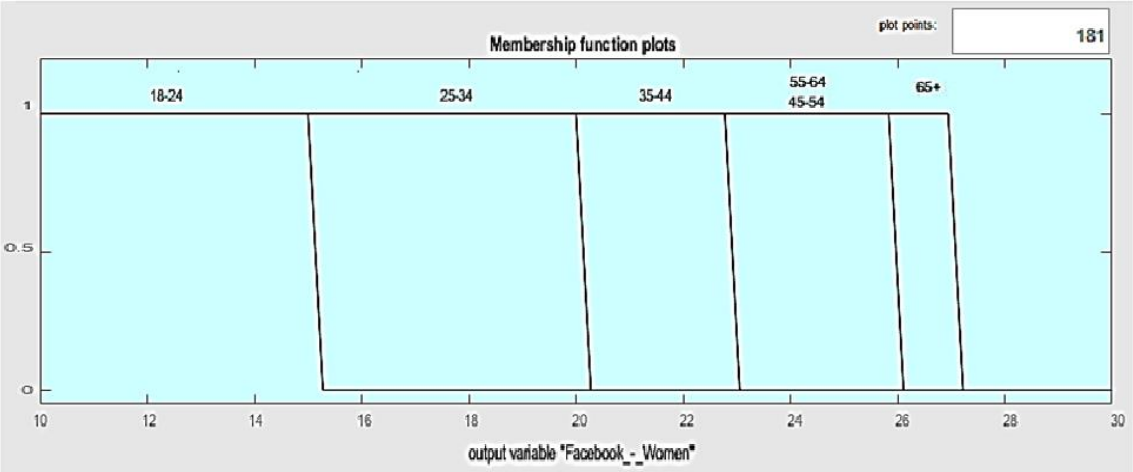

Figure 5. The graph of the current membership function for "Facebook – Women"

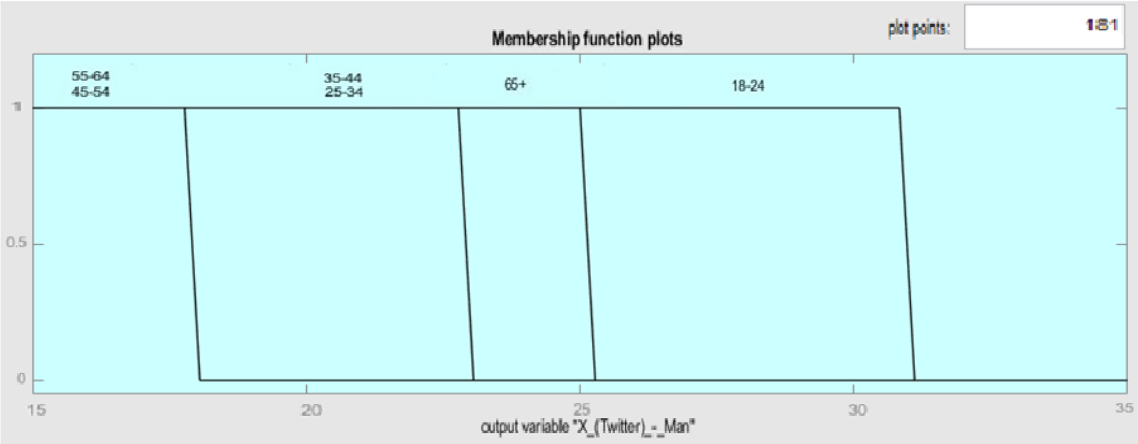

Figure 6. The graph of the current membership function for " X (Twitter) – Man"

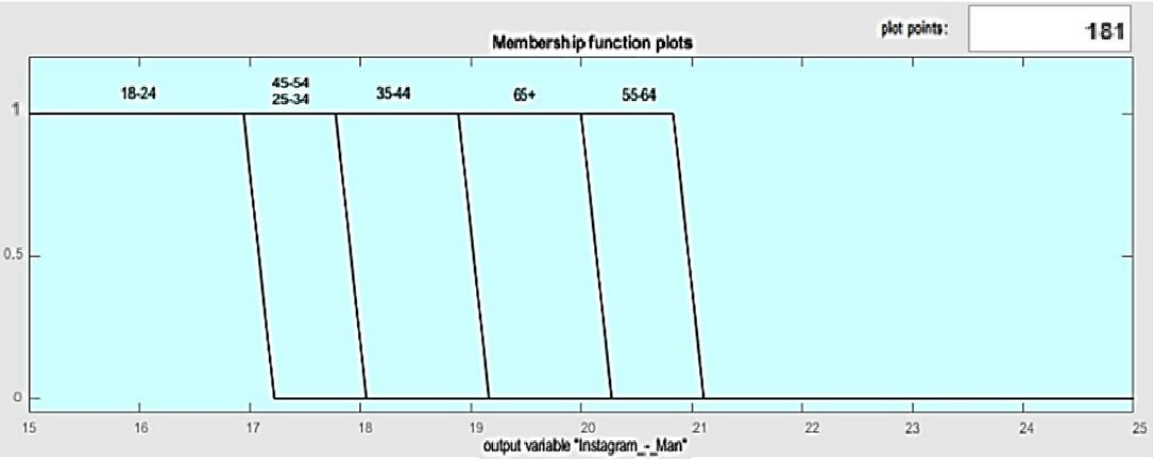

Figure 7. The graph of the current membership function for "Instagram - Man"

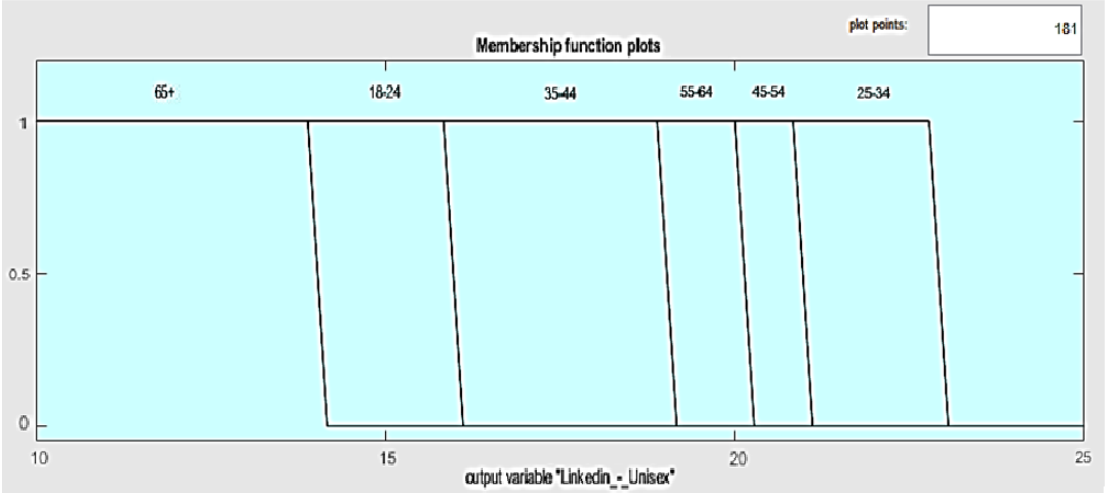

Figure 8. The graph of the current membership function for "LinkedIn – Unisex"

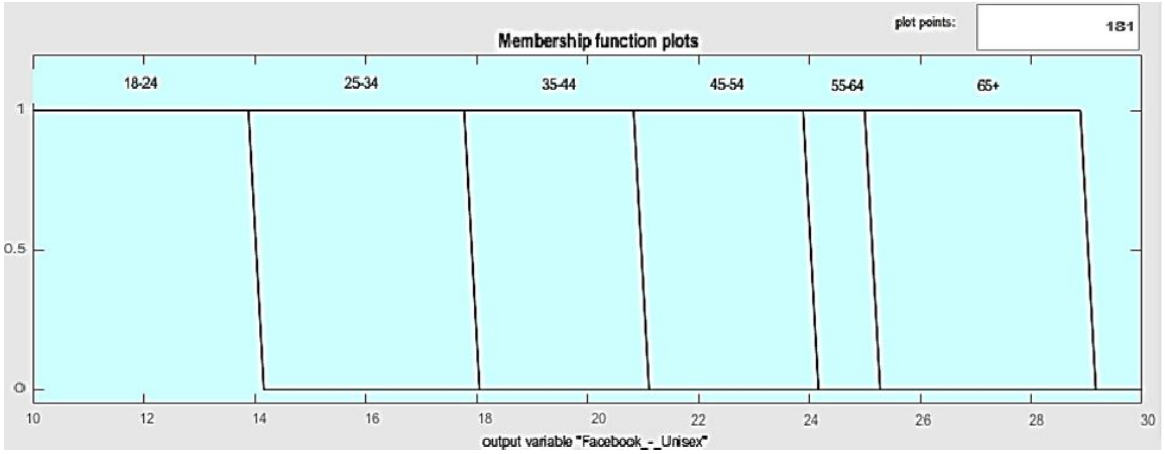

Figure 9. The graph current membership function for "Facebook – Unisex"

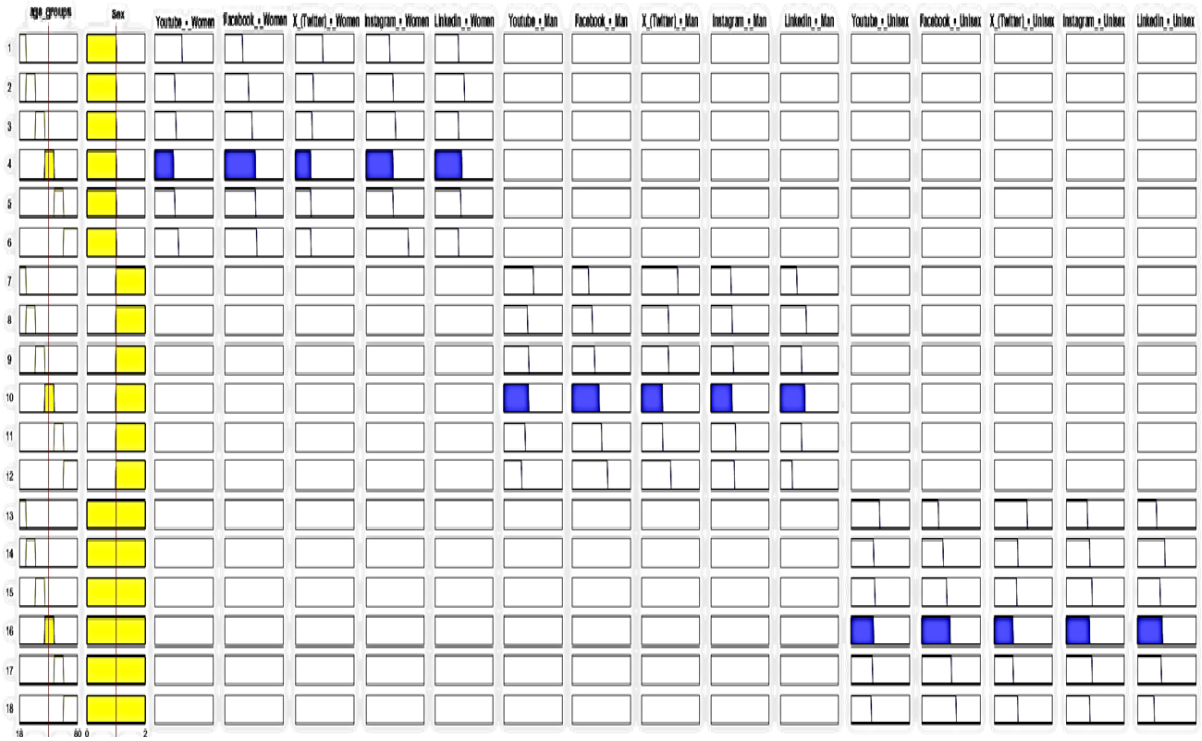

Figure 10. Rule set for fuzzy logic controller using fuzzy logic editor

4. Conclusions

The results and implications of this study were obtained based on the rule set used to determine the distribution of advertising budgets among age groups in social media marketing. The fuzzy logic model developed to optimize the distribution of advertising budgets by age groups in social media marketing was de developed to enable more effective segmentation and targeting of advertising strategies using fuzzy logic. See Figures 11, 12, and 13 as examples.

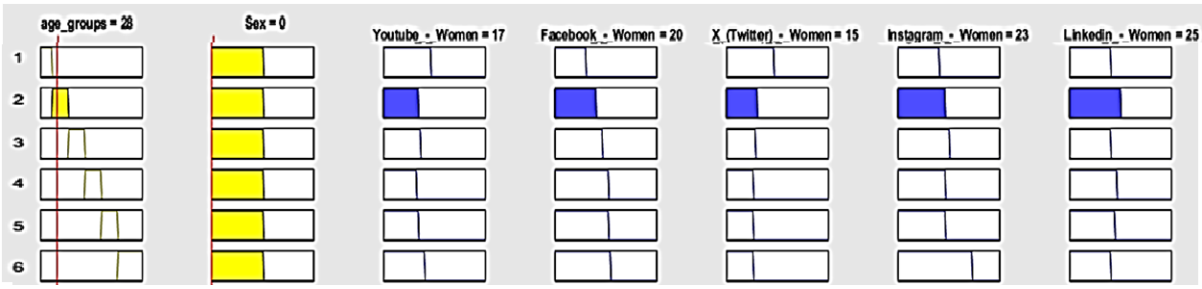

Figure 11. The Effect of Age and Gender on Social Media Advertising Budget Distribution – Example-1

Figure 11 illustrates that the target group is 28 years old and female. The "fuzzy logic controller" indicates that LinkedIn should receive the greatest share of the advertising budget, with 25% of the total. This is followed by Instagram (23%), Facebook (20%), YouTube (17%), and X (Twitter) (15%).

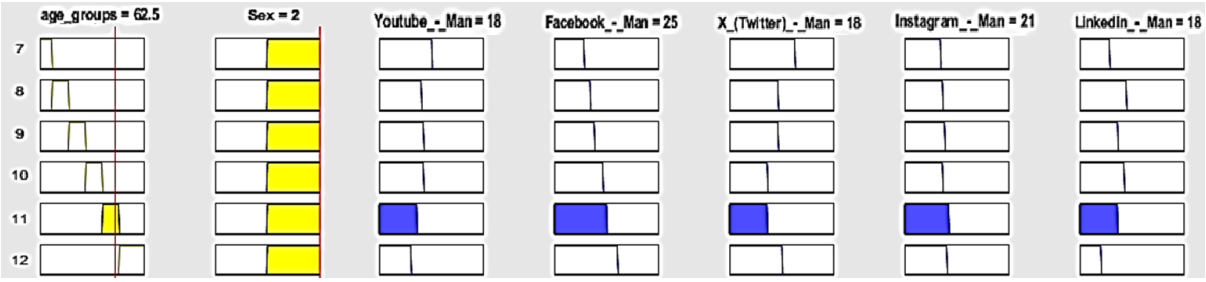

Figure 12. The Effect of Age and Gender on Social Media Advertising Budget Distribution – Example-2

According to Figure 12, the target audience consists of men around the age of 62. In this case, the "fuzzy logic controller" shows that Facebook should have the highest share in the advertising budget with 25%. Facebook is followed by Instagram with 21%, LinkedIn, YouTube and X (Twitter) with 18%.

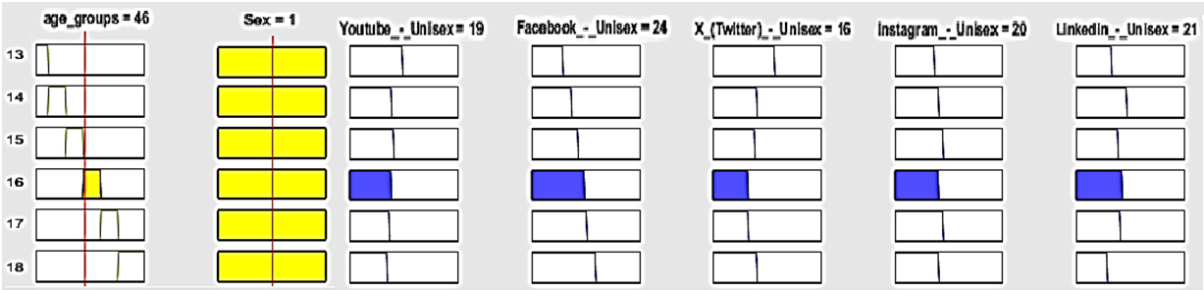

Figure 13. The Effect of Age and Gender on Social Media Advertising Budget Distribution – Example-3

Figure 13 indicates that the target audience is approximately 46 years of age and comprises both women and men, irrespective of gender. The "fuzzy logic controller" suggests that

Facebook should receive the greatest proportion of the advertising budget, at 24%. This is followed by LinkedIn (21%), Instagram (20%), YouTube (19%), and X (Twitter) (16%).

The findings indicate that the fuzzy logic approach can be utilized as a valuable tool in the development of segmentation and targeting strategies in social media marketing. This research demonstrates the applicability of fuzzy logic techniques to enhance efficiency and gain a competitive advantage in social media advertising.

This study highlights the potential of fuzzy logic approach in social media marketing and sheds light on future research. It also calls for future in-depth studies in various fields to overcome the current limitations of fuzzy logic and expand its application areas. First, investigating the integration of fuzzy logic with Machine Learning and Artificial Intelligence techniques could allow for the development of more precise and adaptive models (Vyas, Gupta, Bhargava & Boddu, 2022). In particular, the development of hybrid models can produce more effective solutions by taking advantage of the strengths of both approaches. Second, studies on updating Fuzzy Logic models with real-time data streams can ensure that these models remain up-to-date and accurate in rapidly changing environments such as social media (Lago, Marcjasz, Schutter & Weron, 2021). Furthermore, expanding on demographic and psychographic variables to gain a more comprehensive understanding of social media user behavior can help develop more precise and personalized marketing strategies. Finally, creating user-friendly tools and interfaces with the aim of facilitating the development and interpretation of fuzzy logic models can lead to more widespread adoption of this technology among marketing professionals (Siwicki, 2023). These proposals point to future research directions to increase the potential of fuzzy logic and enable it to spread to wider areas of application.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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