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# A method for optimizing a bidding strategy for online advertising through the use of intuitionistic fuzzy systems

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**Abstract:** Even with the raising popularity of video, audio, and animation content in the Web, the text keeps playing an important role, as well as Web textual ads. Tools for advertising campaigns, such as Google AdWords based on a betting system increase its popularity, but these systems can rapidly consume the user's money. This paper presents a method for optimizing the bids on the betting system through the use of fuzzy logic techniques. In order to lower the cost of the advertising campaign a fuzzy system is implemented on a Google AdWords advertising campaign. A fuzzy inference system is used to control the maximum bidding price of an advertising campaign, by using as inputs the click-through rate and the current maximum bidding price. Another estimation based of the number of the clicks on one of the advertisement is proposed. The estimation used Intuitionistic Fuzzy Set (IFS).
**Keywords:** Interactive evolutionary computation, Fuzzy logic, Genetic algorithm, Advertisement text optimization, Intuitionistic fuzzy set.
**AMS Classification:** 03E72.

## 1 Introduction

In this section we explain several concepts that are necessary to understand this work. A Genetic Algorithm (GA) [12] uses ideas based on the language of natural genetics and biological evolution. In a GA, each state variable corresponds to a gene. Random pairs of chromosomes

are mated using a crossover process, in which new chromosomes inherit genes from either of their parents. In addition, some offspring undergo random mutation, in which one gene changes by a random amount. Offspring selection in the current generation occurs based on the individual's fitness: thus, solutions that are better suited to their environment reproduce, whereas the poorer suited ones die.

Incorporating IEC into the proposed method is achieved by using two previous technologies: Evospace [7] and Evospace-Interactive [8]. Interactive evolutionary computation is a technique that implements a genetic algorithm, but the fitness function is defined in terms of the subjective evaluation of a human being. EvoSpace-Interactive was adapted to the needs of this work by changing the graphical user interface to display the pictures of a hamburger and an automobile, depending on the experiment being conducted. Originally, EvoSpace-Interactive showed two animations, where the user could choose which one looked more appealing. Some modifications needed to be done so EvoSpace-Interactive could be able to translate a chromosome to a text, and viceversa.

Google AdWords [12] is an advertising service by Google for businesses wanting to display ads on Google and its advertising network. The AdWords program enables businesses to set a budget for advertising and only pay when people click the ads. The ad service is largely focused on keywords.

Article spinning is a technique frequently used in search engine optimization practices, which involves the automatic generation of textual content by replacing certain parts of the text with different text of similar meaning.

The main contribution of this paper is a method for optimizing a bidding strategy for online advertising through the use of fuzzy inference systems.

## 2 Related work

Keng and Liu, in 2013 [10], analyzed how websites need to be designed according to the user's personality and their interests, which supports the idea of customizing the advertisement units (and, as a future work, the textual content of a website by using the proposed method) so the users are more appealed by how they are presented. Wu, Zongda, et al. [15] focused on the optimal positioning of an advertisement, rather than what ad to show to the user as a contrast to this work, which focuses on what to show to the user. Fan and Chang [6] in 2011, proposed a software framework to analyze the content from blogs, determine their subject, and recommend advertisements that are relevant to the blog's content; this work proposes the customization of the advertisements so they become likeable by the user, instead of choosing from a pool of advertisements. Dao, Tuan Hung, et al. [5], developed a tool that recommends ads based on an individual's personal information, such as using the user's location to provide better advertisements.

Prediction of stock price variation is a very difficult task, with price movement behaving more like a random walk. The use of fuzzy logic systems is commonly applied to price forecasting and sometimes is used in combination with Neural Networks [3, 4, 14]. These soft computing techniques use quantitative inputs, like technical indices, and qualitative factors, such as political effects to automate stock market forecasting and trend analysis [5].

However, Tung Yen Lai proposed another application, using a Fuzzy System for a personalized Web advertisement selection and recommendation system. In this case, a membership-based advertisement marketing website whose advertisement content is determined by consumer preference [12].

The approach presented in this paper differs from the previous mentioned works in that we concentrate on the text advertisements with an objective of optimizing advertisement campaigns by generating a more persuasive advertisement text for a less expensive campaign. In addition a hybrid approach of IEC and FL is presented for achieving this advertisement optimization, which has not been proposed before in the literature.

## 2 Previous work

In previous work we generated different advertising text versions. Between these versions, optimal versions were sought using IEC because the search space exceeded 24,000 possible combinations.

The reason for the development of this method is the potential to lower monetary costs in advertisement campaigns and the simplification of advertisement logistics. The method uses a template-based generation approach resembling a technique called "Article Spinning". A template-based natural language generation (NLG) [10] approach is used in this work. The technique is simple; each template-based generator consists of:

1) A template string with predefined slots.
2) A vector of options for each slot.

This structure allows the IEC algorithm to evolve the text, using words and phrases as variable parts that change according to the subjective evaluation of the people who interact with the algorithm.

A couple of texts are shown to the user in a web interface. The user chooses the text, which he considers to be the most attractive, by clicking on it. The genetic algorithm uses the selections made by the users at the moment of the evolution of the texts. After users have evaluated chromosomes, the chromosomes or texts that were more attractive to the users have a better possibility of being chosen. These new chromosomes are stored in a database, and they will be chosen later by the algorithm to be shown in the web interface to the user. Each text version is stored with the number of times it has been shown to a user, and the number of times a user has chosen it to be the most attractive.

After several generations, the fittest individuals are selected, and in another experiment are compared against the chosen combinations. To demonstrate the efficacy of the evolved texts, they are compared against a combination chosen by an expert in a field related to marketing. For this comparison, three tests were performed: memory, recognition, and persuasion. The obtained results show that IEC can be effectively used to increase the efficacy of an advertising text.

The evolution of advertisement texts written by an inexperienced person in the field of marketing, through the use of interactive evolutionary computing and fuzzy logic techniques, is a viable method for creating texts with a higher probability of persuading consumers into buying the advertised product.

This work serves as proof that IEC is a promising area for performing valence shifting to a text, and that it has the possibility of matching the performance that an expert would achieve when choosing a combination of words from a template. The proposed method could prove to be a valuable tool for the creation process of a marketing campaign that involves advertisement texts.

## *Intuitionistic Fuzzy Sets*

Intuitionistic Fuzzy Sets (IFSs) [1, 2] are defined as extensions of ordinary fuzzy sets. All results that are valid for fuzzy sets can be transformed for IFSs, too.

On the other hand, there have been defined over IFSs not only operations similar to those of ordinary fuzzy sets, but also operators that cannot be defined in the case of ordinary fuzzy sets (see [1, 2]).

Let the set $E$ be fixed. An IFS $A$ in $E$ is an object of the following form:

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle \mid x \in E\},$$

where functions $\mu_A : E \to [0, 1]$ and $\nu_A : E \to [0, 1]$ define the degree of membership and the degree of non-membership of the element $x \in E$, respectively, and for every $x \in E$:

$$0 \leq \mu_A(x) + \nu_A(x) \leq 1$$

For every $x \in E$, let

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x).$$

Therefore, the function $\pi$ determines the degree of uncertainty.

Obviously, for every ordinary fuzzy set $\pi_A(x) = 0$ for each $x \in E$, these sets have the form:

$$\{\langle x, \mu_A(x), 1 - \mu_A(x)\rangle \mid x \in E\}.$$

Let a universe $E$ be given. One of the geometrical interpretations of the IFSs uses figure $F$ on Figure 1:

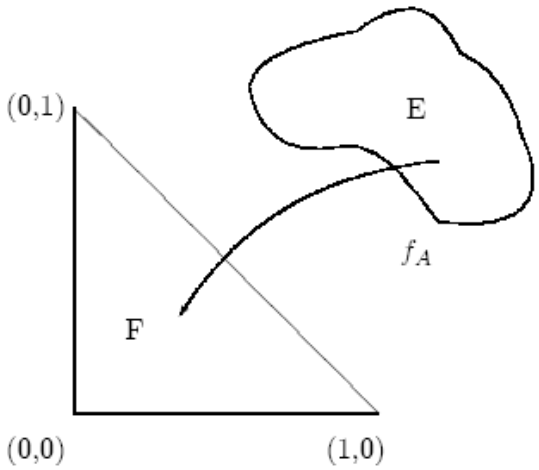


Figure 1. Intuitionistic fuzzy triangle

# 3 Proposed optimization

In order to lower the cost of the advertising campaign, a fuzzy inference system (FIS) is used as the second part of this work to control the maximum bidding price of an advertising campaign, by using as inputs the click-through rate and the current maximum bidding price. Although these modules are not integrated in an implementation yet, they would be integrated in the following manner: the FIS controller minimizes the CPR, and after a certain period of time, communicates this CPR, and the number of clicks received by the advertising campaign is used as a performance measure, to the IEC system; the IEC system then calculates scores, in terms of the CPR and number of clicks, for all the advertising campaigns, and uses the scores to perform the evolutionary process.

A Mamdani type fuzzy controller [13] is implemented and the input variables are: time, CTR and price. The output variable is the price and Gaussian membership functions are used for each linguistic value. The linguistic values are: low, medium and high. The fuzzy rules were created based on the knowledge of an expert. The data used to tune the fuzzy controller is the data generated, in real-time, by Google Adwords. The Adwords API provides a method to obtain the current maximum bidding price of an advertising campaign, as well as other features such as the CTR, the number of impressions, and the average cost per click.

# 4 Experiments

A Mamdani type fuzzy controller (shown in Fig. 2) is implemented and the input variables are: time, CTR and price. The output variable is the price and Gaussian membership functions are used for each linguistic value. The linguistic values are: low, medium and high. The fuzzy rules were created based on the knowledge of an expert. For example, the fuzzy rule: “If ctr is low and price is low then nprice is high”, means that: if the CTR (Average Click-Through Rate) is low (around 2) and the current maximum bidding price is low (around $1 MXN), then the nprice (New Price) is high (around $4 MXN). The interpretation of the other fuzzy rules can be done in a similar way.

ifctr is low and price is low then nprice is high
ifctr is low and price is medium then nprice is medium
ifctr is low and price is high then nprice is low
ifctr is medium and price is low then nprice is medium
ifctr is medium and price is medium then nprice is high
ifctr is medium and price is high then nprice is medium
ifctr is high and price is low then nprice is low
ifctr is high and price is medium then nprice is medium
ifctr is high and price is high then nprice is medium

Figure 2. The fuzzy rules of the fuzzy controller.

The parameters of the Gaussian membership functions (shown in Fig. 3) were established semi-arbitrarily, and only function to maintain a symmetrical design and perform in a way the authors considered would help the fuzzy controller perform well.

The data used to tune the fuzzy controller is the data generated, in real-time, by Google Adwords. The Adwords API provides a method to obtain the current maximum bidding price of an advertising campaign, as well as other features such as the CTR, the number of impressions, and the average cost per click.

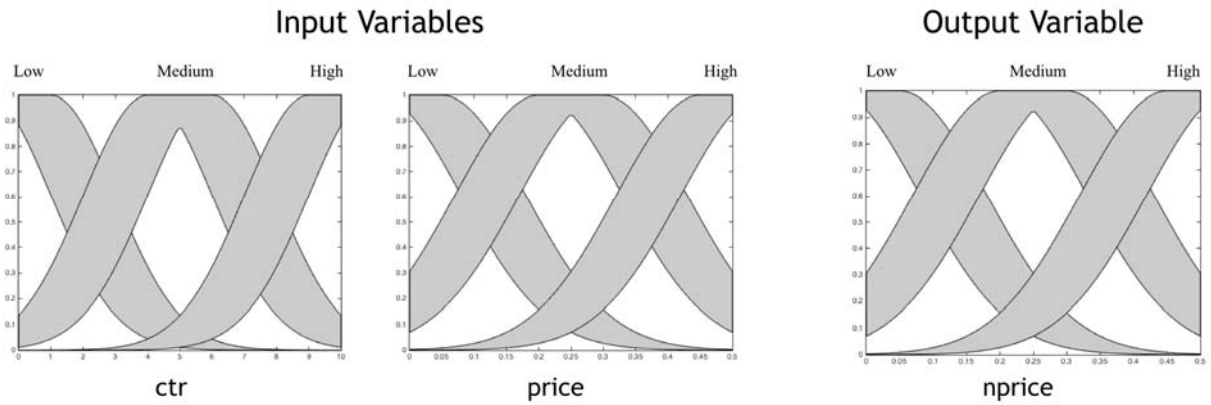


Figure 3. Membership functions

For this experiment, 60 AdWords campaigns were run at the same time, for a period of 24 hours. 30 of those campaigns were set to adjust their maximum bidding price automatically, and the remaining 30 campaigns were set to adjust their maximum bidding price manually. This procedure is usually called a bidding strategy. Those campaigns that were optimized automatically are controlled by the Google AdWords' algorithm, while those set to be optimized manually are controlled by a type-1 fuzzy inference system (T1-FIS).

After the period of 24 hours, a hypothesis statistical testing compared the statistics generated by each of the controllers. The features that were compared were: number of clicks, CTR, and average cost per click (CPC) (shown in Tables 1, 2 and 3).

| Experiment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Google | 20 | **23** | 24 | 23 | 18 | 24 | 25 | 21 | **24** | **24** | 23 | 22 | 22 | **24** | 19 | **26** | 22 | 20 | 17 | 21 | 18 | 22 | 17 | 19 | 22 | 23 | 19 | 15 | 17 | 17 |
| EvoWords | **24** | 18 | **25** | **29** | **23** | **32** | **29** | **27** | 23 | 22 | **25** | **26** | **30** | 23 | **25** | 25 | **24** | **31** | **24** | **26** | **31** | **31** | **30** | **23** | **29** | **28** | **27** | **27** | **28** | **26** |

Table 1. Experiment of EvoWords vs. *Google AdWords* method (Number of clicks)

| Experiment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Google | 1.95 | 1.78 | 1.49 | 1.4 | **1.94** | **2.17** | 2.17 | **2.97** | 1.36 | 1.57 | 1.87 | 1.8 | 1.97 | 1.4 | 2.01 | 1.92 | 1.4 | 1.51 | **2.53** | 1.55 | 1.34 | 1.51 | **2.59** | **2.58** | 1.56 | 1.97 | 1.37 | 1.48 | **1.89** | **2** |
| EvoWords | **2.21** | **2.6** | **1.7** | **2.83** | 1.43 | 1.38 | **2.4** | 1.86 | **1.66** | **1.67** | **2.04** | **2.08** | **2.28** | **2** | **2.27** | **2.37** | **1.48** | **1.8** | 1.5 | **1.89** | **1.68** | **2.22** | 1.68 | 1.35 | **2.19** | **2.02** | **1.83** | **1.98** | 1.51 | 1.97 |

Table 2. Experiment of EvoWords vs. *Google AdWords* method (CTR)

| Experiment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Google | 0.26 | 0.29 | **0.23** | 0.22 | 0.27 | 0.25 | **0.22** | 0.21 | **0.21** | **0.21** | 0.28 | 0.23 | 0.25 | 0.24 | 0.24 | 0.28 | **0.21** | 0.23 | 0.27 | 0.22 | 0.25 | 0.21 | 0.28 | 0.27 | 0.20 | 0.29 | 0.26 | 0.29 | 0.26 | 0.27 |
| EvoWords | **0.25** | 0.29 | 0.25 | **0.21** | **0.25** | **0.18** | 0.24 | **0.20** | 0.23 | 0.24 | **0.21** | **0.22** | **0.19** | 0.24 | **0.21** | **0.22** | 0.24 | **0.21** | **0.21** | 0.22 | **0.18** | **0.18** | **0.17** | 0.27 | 0.20 | **0.18** | **0.20** | **0.19** | **0.19** | **0.21** |

Table 3. Experiment of EvoWords vs. *Google AdWords* method (CPC)

In some cases there is still a need for a formal interpretation of the results, therefore a statistical test is needed. The test is performed for two sample means with a significance level of 5%, to determine whether the proposed method is better than the Google AdWords method as measured by the amount of clicks and the obtained cost per click. The hypotheses that are considered in the clicks case are:

$$H0: EvoWords <= Google\ AdWords$$
$$H1: EvoWords > Google\ AdWords.$$
$$t - value = 6.7204, critical\ t - value = 2.002411.$$

Based on the t-value we have found statistical evidence that the proposed method outperforms the clicks obtained with the Google AdWords method. The hypotheses that are considered in the cost per click case are:

$$H0: EvoWords >= Google\ AdWords$$
$$H1: EvoWords < Google\ AdWords.$$
$$t - value = -4.0227, critical\ t - value = -2.001736.$$

Based on the t-value we have found statistical evidence that the proposed method outperforms the cost per click obtained with the Google AdWords method. On the other hand, the hypotheses that are considered in CTR case are:

$$H0: EvoWords <= Google\ AdWords$$
$$H: EvoWords > Google\ AdWords$$
$$t - value = 0.9178, Critical\ t - value = 2.002436.$$

Based on the t-value we have not found sufficient statistical evidence to reject the null hypothesis with a significant level of 5% or less on the CTR experiments.

This means that the results of the proposed method are better because the generated advertisement is more efficient and with the advertisement campaign using a fuzzy controller we can make a campaign that is less expensive.

## *Intuitionistic Fuzzy Estimation*

The $i$-th advertisement, $i = 1, 2, \ldots, n$ has $c_i$ clicks. Let $c_{min}$ represent the minimal number of clicks without this of the $i$-th advertisement $c_{min} = min(c_1, \ldots, c_i, \ldots, c_n)$. Then, $c_{max}$ represents the maximal number of the clicks of the advertisements, $c_{max} = max(c_1, \ldots, c_i, \ldots, c_n)$.

In this case the evaluations of the $i$-th advertisement $\langle \mu_i, \eta_i \rangle$, $\mu_i, \eta_i \in [0, 1]$, $\mu_i + \eta_i \leq 1$ are:

$$\mu_i = \frac{c_i}{c_{max}},$$

$$\nu_i = \begin{cases} \frac{c_{min} - c_i}{c_{max}}, & \text{if } c_{min} \geq c_i \\ 0, & \text{if } c_{min} < c_i \end{cases},$$

The degree of uncertainty $\pi_i$ is

$$\pi_i = \begin{cases} \frac{c_{max} - c_i - (c_{min} - c_i)}{c_{max}}, & \text{if } c_{min} \geq c_i \\ \frac{c_{max} - c_i}{c_{max}}, & \text{if } c_{min} < c_i \end{cases}.$$

$$\pi = 1 - \mu - \nu.$$

Estimates indicating the degree of usability $\mu$ and degree of no usability $\nu$ are ordered pairs $\langle \mu, \eta \rangle$, of real numbers of multiple $[0, 1] \times [0, 1]$. The degree $\pi = 1 - \mu - \nu$ present when some client clicks somewhere else.

In the beginning, when not yet yielded any information we use value $\langle 0, 0 \rangle$. The current $(k+1)$-first for $k \geq 0$ score is calculated based on previous assessments by the formula:

$$\langle \mu_{k+1}, \nu_{k+1} \rangle = \langle \frac{\mu_k k + m}{k+1}, \frac{\nu_k k + n}{k+1} \rangle,$$

where $\langle \mu_k, \nu_k \rangle$ is the previous assessment, $\langle m, n \rangle$ is the assessment of the current advertisement, $m, n \in [0, 1]$ and $m + n \leq 1$.

# 5 Conclusions

A fuzzy inference system would be part of the solution to control the bid amount of each ad unit, and help in the process of determining which ad units should be removed or kept longer in the advertisement campaign, and thus helping indirectly improve the evolutionary process.

In addition, using a fuzzy system to regulate prices of the Google AdWords campaign seems to have a promising future, but we still need to perform more experiments. We also plan to improve the design of the fuzzy system as in other recent works, for example we will try optimizing its design with bio-inspired algorithms.

Another estimation based of the number of the clicks on one of the advertisement is proposed. The estimation used Intuitionistic Fuzzy Set (IFS).

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