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An approach to obtain the generalized mixed linear stress function for known owa weights with artificial bee colony algorithm

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Abstract

OWA (Ordered Weighted Averaging) is a flexible aggregation operator which is come up with Yager to create a decision function in multi-criteria decision making. It is possible to determine how optimistic or pessimistic the decision maker's opinion with the value obtained from the weights of this operator. The determination of OWA weights cannot provide characterization by itself. If it is desired to aggregate various sized objects in terms of generalization and reusability of OWA weights, a more general form is needed. In this study, we propose the parameterized piecewise linear stress function and the approach to characterize OWA weights. The stress function is expressed by parameters which are obtained by artificial bee colony algorithm. Also the weights are approximately found by using parameters.

Keywords – OWA operator, aggregation, artificial bee colony algorithm.

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INTRODUCTION

The aggregation of the criterion functions to form decision functions is important in many disciplines. One of the general cases is to satisfy all the criteria and the other is to satisfy the required criteria. To form the criteria function these two cases, 'or' and 'and' are used together. Each decision maker has different perspective so a decision function for multi-criteria problem is flexible and productive with various strategies. The ordered weighted averaging operator (OWA) which was proposed by provides a parametrized class of mean operators. Most applications of OWA Operator have been introduced to areas such as decision making, intelligent systems, neural networks, fuzzy systems, control and communication networks in a short time (Bordogna & Pasi, 1995; Yager & Kacprzyk, 1997)

If OWA operator is considered as an n -dimensional function; $f: R^n \to R$ and the weight vector associated with this funciton is $W = [w_1, w_2, \dots, w_n]$ such that

$\sum_{j=1}^{n} w_j = 1$ and $w_j \epsilon [0,1],\ j = 1, \dots, n$.

The function with these constraint is as follows

$$f(a_1, a_2, \dots, a_n) = \sum_{j=1}^{n} w_j a_{(j)}$$

where $a_{(j)}$ value in summation is the j.th biggest value in the collection of $a_1, a_2, \dots, a_n$.

The most important and fundamental part of the OWA operator is "sorting". The argument w_i is related to the i.th position of the sorted argument, not related to the particular a_i value.

Yager defines the "orness" function to determine the type of aggregation according to the values.

$$orness(W) = \frac{1}{n-1} \sum_{i=1}^{n} (n-i) w_i.$$

"Orness" value takes a value in the range [0,1]. If $\text{orness} = 0$ (for ex. $(w = [0, 0, \dots, 1])$) then decision maker has pessimistic approach and that means the logical 'and' operator has been used. If $\text{orness} = 1$ (for ex. $(w = [1, 0, \dots, 0])$) then decision maker has optimistic approach and that means the logical 'or' operator has been used. Another situation is $\text{orness} = 1/2$ (for ex. $\left(w = \left[\frac{1}{n}, \frac{1}{n}, \dots, \frac{1}{n}\right]\right)$. That means decision maker has balanced approach so uses arithmetic mean operator.

Another measure defined by Yager is "entropy" ("dispersion"):

$$Disp(W) = \sum_{i=1}^{n} w_i \ln w_i.$$

Dispersion value gives information about how much of the information in the arguments is used while calculating the aggregation value based on the weight vector. The value of the dispersion can take a value in $[0, \ln(n)]$.

One of the major challenges in using the OWA operators is to generate its weights. A number of methods are proposed to find the weights associated with the OWA operator (Nasiboglu & Tezel, 2016). In this study, we propose the generalized mixed linear stress function and the approach to characterize OWA weights. The stress function is expressed by parameters which are obtained by artificial bee colony algorithm. Also the weights are approximately found via using parameters (Filev & Yager, 1998; Nasiboglu & Tezel, 2016).

I. GENERALIZED MIXED LINEAR STRESS FUNCTIONS (GMLSF)

The most important approach to obtaining OWA weights is function method that is proposed by Yager. Let F be a function defined as $\text{F}: [0,1] \to [0,1]$ with equalities $\text{F}(0) = 0$ and $\text{F}(1) = 1$ and inequalities $F(x) \geq \text{F}(\text{y})$ for all $\text{x} > \text{y}$. Under these constraints F is named basic unit interval monotonic function (BUM). Using BUM function, the OWA weights are produced as follows for $j = 1, \dots, n$:

$$w\_j = F(j/n) - F((j-1)/n).$$

It is obvious that w_j's are in the unit interval $[0,1]$ and their summation is equal to 1.

F which is non-negative function is defined with h(x) such that $\mathrm{h(x)} \geq 0$ and $\mathrm{h}: [0,1] \rightarrow R^{+}$ then the BUM function structure is not corrupted.

$$\mathrm{F(x)} = 1/K \int_0^x h(y)dy,$$

Where;

$$\mathrm{K} = \int_0^1 h(y)dy.$$

The function h (x) in the equation is called the stress function and indicates where F is located along the x-axis. In other words, h(x) function refers to where the OWA weights obtained by F function are located (stretched).

OWA weights can always be obtained with a given stress function h(x) and BUM function F(x) (Yager & Kacprzyk, 1997)

Weights are expressed in the form;

$$w_j = F\left(\frac{j}{n}\right) - F\left(\frac{j-1}{n}\right).$$

If this equation is constructed as follows;

$$w_j = F(j/n) - F(j/n - 1/n)$$

and 1/n denotes as Δ ;

$$w_j = F\left(\frac{j}{n}\right) - F\left(\frac{j}{n} - \Delta\right).$$

And the following equation is more understandable.

$$w_j = \left(\frac{F\left(\frac{j}{n}\right) - F\left(\frac{j}{n} - \Delta\right)}{\Delta}\right) \Delta.$$

Equation is expressed for small Δ values (big n values) as above gives the derivative of function F at x = j / n.

$$w_j = \frac{1}{K}\, h\left(\frac{j}{n}\right) \Delta.$$

Because of Δ denotes 1/n ;

$$w_j = \frac{1}{K}\, h\left(\frac{j}{n}\right) \frac{1}{n} = \widetilde{w}_j.$$

We can specify the expression $\widetilde{w}_j$ as the approximation of the weights w_j obtained from the original method.

Weights must be normalized to ensure that the sum of the approximate weights obtained from the stress function is equal to 1.

$$w_j = \frac{\frac{1}{K} h\left(\frac{j}{n}\right) \frac{1}{n}}{\sum_{j=1}^{n} \frac{1}{K} h\left(\frac{j}{n}\right) \frac{1}{n}} = \frac{h\left(\frac{j}{n}\right)}{\sum_{j=1}^{n} h\left(\frac{j}{n}\right)}.$$

There are many useful features of obtaining OWA weights with the stress function. One can use the same function for any n value. So, a consistent weight vector can be generated according to different argument numbers. The other feature allows the user to easily understand the nature of the results of the OWA aggregation operator.

More generally, we can create stress functions using a mixture of linear components. All kind of stress functions known in the literature can be represented using three linear segments. If the linear function converges to a constant, all weights in a constant range are the same, and the weights, which are in a linear range, degrade linearly. Therefore, a total of six points are required to represent the stress functions with three linear segments, each represented by two points. As shown in Figure 1, however, here the y-axis is represented by six dots and the x-axis by four dots because the linear segments are continuous with respect to the x-axis. The above mentioned stress function is called generalized mixed linear stress functions. Expressing stress functions with three part piecewise lines is shown in Figure 1.

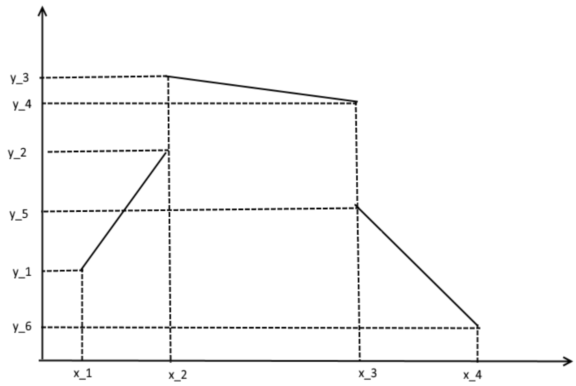


Figure 1. Expressing stress functions with three lines.

II- Artificial Bee Colony (ABC) Algorithm

The artificial bee colony (ABC) algorithm which models the intelligent behavior of bee colonies and their behavior in the food search process, was developed by D. Karaboga in 2005 as an optimization tool inspired by the modeling of food searches in nature. The number of bees in the algorithm is equal to the total food source. The locations of the food sources of the bee colon represent the possible solutions of the problem to be solved, and the quantity of nectar represents the quality of the solution. The ABC algorithm tries to locate the source that has the most nectar and tries to find the point (solution) that gives the minimum or maximum of the problem from the search solutions. Employed bees responsible for bringing the nectar from the chosen food source and transferring information about resources. Bees in search of resources are unemployed. These are two kinds of bees. One is onlooker bees who are looking for a random source, and the other is scout bees who are going to the new source with information coming from the shell (Karaboga, 2014)

The information exchange is important for the formation of common knowledge.

Each source of nectar should be taken by the employed bees;

The number of employees should be equal to the total food source;

The number of employed bees should equal the number of onlooker bees.

With the above assumptions, the basic steps of the algorithm works like this:

Step 1. Generate initial food source.
Step 2. Return to Step 2 unless stop criterion is satisfied.
Step 3. Send employed bees to food sources and determine the amount of nectar and finding new food sources.
Step 4. Calculate the probabilities of selecting sources based on the amount of nectar.
Step 5. Send onlooker bees to food sources according to probability values of sources.
Step 6. Leave out the exhausted resources.
Step 7. Send scout bees for new resources.
Step 8. Get the best nectar source into memory.
Step 9. Return Step 2.
Step 10. Show the best solution.

Food source at starting is produced with random production between the upper and lower limits of each parameter. An error value or the maximum number of cycles can be used as the stopping criterion. Then the employed bees go to the food sources, they have to set a new resource in the neighborhood of this resource and compare it to the available resource in terms of the amount of nectar and get the best memory. After making sure that the new resources are within the limits of the parameters, fitness value calculation will do. If the new resource is better according to fitness value, the old resource is deleted and the new resource is stored. Otherwise, the failure number of the old source is increased. It resets when it develops.

In calculating the probabilities of selection of resources, any selection scheme such that roulette technique, tournament method or ranking can be used by taking into account the fitness value. Any technique is be used to select source but actually the source will be selected according to the amount of nectar, in the other meaning the source will be selected according to maximum fitness value. At the end of a cycle (all scout bees and employed bees completed the search processes) the solution improvement counters are checked. Thus it is checked whether the bees benefit from the sources or whether the nectar is consumed or not. If the improvement counter does not have a certain threshold, the employed bees searched for a new resource by releasing the source of interest. Finally source with most nectar is found.

II. Linearization Of Gmlsf Parametres With Abc Algorithm

In this study, generalized stress function which can represent all known stress functions, is obtained from the parameters calculated by the artificial bee colony algorithm.

The algorithm generates random solutions as many as the number of food sources determined at the beginning. Then it finds the optimum weights and parameter values of function according to the fitness values and the number of failure.

The parameters of the stress function obtained from the ABC algorithm are initially determined as in Figure 2:

Figure 2. The parameters of the stress function.

x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4	y_5	y_6

In other words, each of the food sources (solutions) which are initially identified that consists of 10 parameters. The parameters related to each of these sources are randomly generated with the maximum and minimum limits of the parameters. The amount of nectar is determined by sending employed bees to food sources. It must be a specific function to determine the amount of nectar.

It is possible to visualize the generalized stress function with the couple values which are found by the help of a function which is in ABC algorithm.

III. Experiments

Examples of the application are given for three of the stress functions. After running of the algorithm for OWA weights with two-tailed stress function is shown in Figure 3. The visualization of the related parameters for this case is shown in Figure 4.

Another stress function, the Centering-Type Linear Stress Function, is shown in Figure 5 In this function, the number of data is 50 and the number of iterations is 2000.

Figure 3. Obtained OWA Weights From ABC Algorithm.

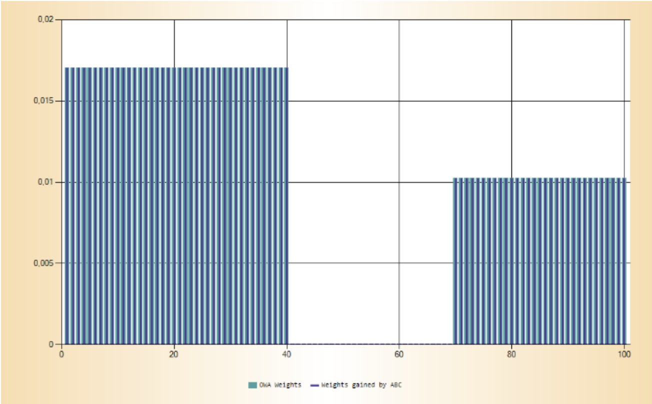


Figure 4. Parametrized representation of the two-tailed stress function.

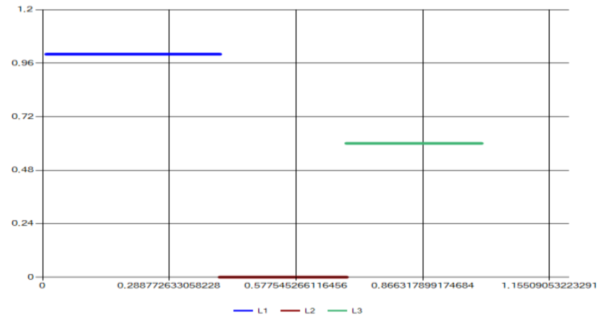
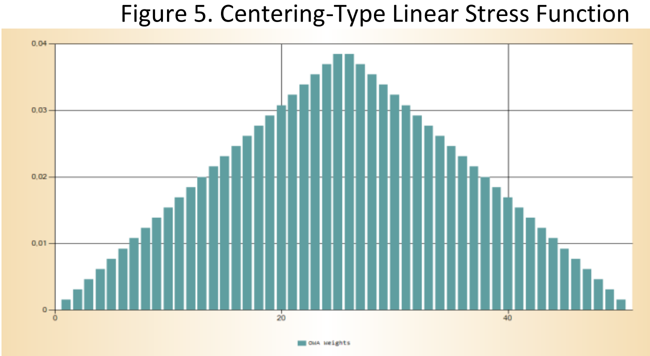


Figure 5. Centering-Type Linear Stress Function



If the algorithm works with 10 as the number of failures, the graph of the parameterized functions is shown in Figure 6. The number of failures and the number of arguments are effective in improving the parametrized graph. The stress function expressed by the combination of fixed and linear functions is shown in Figure 7. The number of arguments is set 100 ($\alpha = 0.3 \; and \; \beta = 0.5$).

The sum of square errors varies with the different value of the number of failures. If failure number is taken as 10 then SSE=0.00000011 and if it is taken as 30 SSE=0.00000002.

Figure 6. Parametrized Function with Failure Number 10.

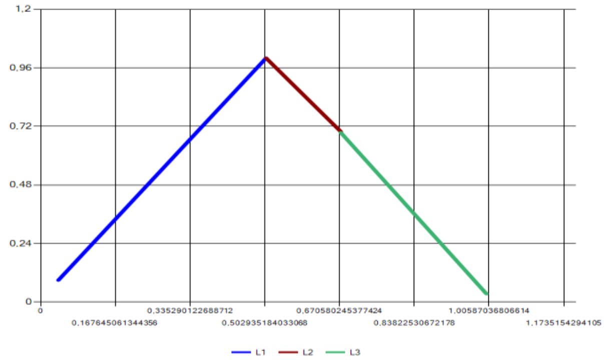
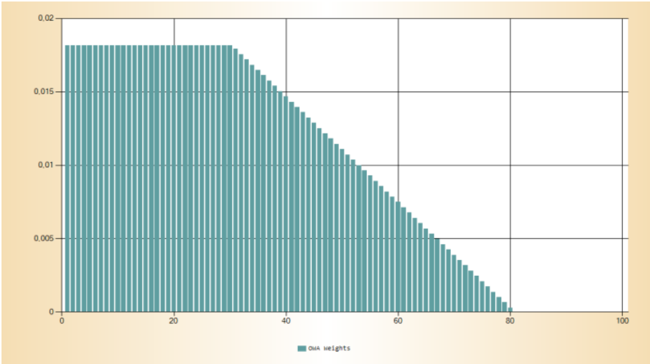


Figure 7. Parametrized Function with Failure Number 50.



IV. Results & Discussion

In this paper, we introduce the new approach for generalization of OWA weights. This generalization was realized by introducing a methodology based on the idea of the combination of artificial bee colony algorithm and using generalized mixed linear stress functions. At this point, a number of useful properties are obtained. First, the same function is used for any n, since OWA weights are generalized by a function. For this reason, we can obtain consistent OWA weights for object sets of different sizes. Another useful feature of this approach is that it allows a user to easily characterize the OWA operator with the help of the stress function. The stress function gives us a very powerful visual tool. In this way, a user can easily see where the weights are to be allocated. The visualization reflects the strategy of a decision-maker which is parameterized by the ABC algorithm. A visual knowledge about the attitudinal character of user is obtained with the line equations generated by parameters.

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