A BL-Algebra-Based Method for Fuzzy Screening

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ABSTRACT— ***A fuzzy screening algorithm was introduced by Yager in 1993. In this paper a new approach based on type-2 fuzzy sets is illustrated to tackle screening problems. The method heavily relies on the properties of a suitable algebraic structure. The two algorithms are applied to the same case study and the results are compared.***

Keywords – Type-2 fuzzy sets, BL-algebras, fuzzy screening

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1. INTRODUCTION

Screening problems involve to single out, given a class of alternatives, a subset on which further investigation could be carried out. It is clear that this class of problems are of great interest and fuzzy methods have been developed to deal with them in several application fields [1, 2, 3, 10, 11, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23]. In particular, in 1993 Yager [18] proposed an interesting fuzzy screening algorithm that involves two stages. First, alternatives are evaluated by experts by rating each alternative with respect to the criteria, these latter possibly having a level of importance attached to them. In order to facilitate the evaluator's job, the values to be used for the evaluation belong to a set of linguistic labels. The second stage of the procedure involves the aggregation of expert's evaluations to eventually get a linguistic value for each alternative. Then the decision maker can use these linguistic value to select the best alternative.

In this paper an algebraic approach to fuzzy screening is illustrated, it is based on selecting attributes and linguistic terms and then representing the latter by triangular fuzzy numbers. Then suitable strings (type-2 fuzzy sets) are constructed whose composition gives the final results.

The paper is organized as follows. In section 2 Yager's procedure is illustrated. Section 3 summarizes the basic features of the BL-algebra. Next section presents the algebraic approach to fuzzy screening and in Section 5 a case study is illustrated Then the two methods are applied to the case study and their results are finally compared.

2. YAGER'S APPROACH TO FUZZY SCREENING

Yager [18] tackles the problem of fuzzy screening as follows:

- a collection **X**= { $X_1, \ldots, X_p$ } of alternative solutions
- a group of experts whose opinion affects the screening of the alternatives. The set of experts is denoted by **A** = { $A_1, \ldots, A_r$}. Generally *r* is smaller than *p* .
- a collection **C** = {$C_1, \ldots, C_n$ } of criteria that are considered relevant for singling out the objects.

To each alternative is attached a small quantity of information that supports its candidature as the best solution. For any alternative an expert assesses how the alternative satisfies each of the criteria in the set C. These ratings are expressed by a suitable scale **S** = { $S_1, \ldots, S_m$}.

Thus for each alternative Xithe expert k gives n values. [$X_{ik}(C_1)$,$X_{ik}(C_2)$, …, $X_{ik}(C_n)$], where $\mathbf{X_{ik}(C_j)}$ is the rating of the i-th alternative about the j-th criterion given by the k-th expert. Any $X_{ik}(C_j)$ is an element of the set S.

The criteria may have different importance. Thus, each expert rates them according to his/her opinion. With $Imp_i(\mathbf{C_j})$ one denotes the importance assigned to the j-th criterion by the i-th expert.

The formula used to find the rating of each alternative given by an expert is $\mathbf{X_{ik}}= \min_j [Neg(Imp_k(C_j)) \vee X_{ik}(C_j)]$, where $Neg(Imp_k(C_j)) = Neg(S_i)) = S_{m-i}$.For each alternative it is assumed that there are r experts and r ratings { X_{i1} , X_{i2} , … , X_{ir} } where X_{ik} is the rating of the i-th alternative given by the k-th expert. Thus one has to combine the rating of the experts in order to get an overall rating for each alternative. Yager assumes that all experts have the same importance.

The first step in this procedure is to define an aggregation function Q. This function can be viewed as a generalization of the idea "how many experts should agree on an alternative in order that the latter be selected?". In particular, for each number i (i=1…r) the decision-maker has to give a value Q(i) denoting the degree of satisfaction to be assigned to an alternative if iamong the experts think that the alternative is deserving. The values for Q(i) belong to the scale S = { $S_1, S_2, \ldots, S_n$ }. It is worth noting that Q(i) should satisfy the following properties in order to preserve rationality:

1. If the number of experts agreeing on an alternative grows, the final degree of satisfaction consequently grows:

Q(*i*) ≥ Q(*j*) if i>j.
2. If all experts agree on considering an alternative satisfactory, its final degree should achieve the highest value: Q(*r*) = Perfect .

Yager presents the function $Q(k) = S_{b(k)}$, where b(k) = Int [1 + (k * ((q – 1) / r)]. Whatever may be the values of q and r, one has: $Q(0) = S_1$, $Q(r) = S_q$.

In order to aggregate the opinions of the experts, the first step consists in a decreasing ordering of the X_{ik} . Let $B_j$be the j-th highest value among those associated by the experts with the alternative. The rating of the i-th alternative, denoted by X_i , is given by the following formula:

$X_i = \max_{j = 1, \ldots, r} [Q(j) \wedge B_j]$,

where ∧ denotes the minimum between two values. It is worth emphasizing that the role of sum in the traditional arithmetic mean is played by the choice of the maximum. The term $Q(j) \wedge B_j$acts as a weight, but really one asks that at least j experts support an alternative.

3. A BL-ALGEBRA ON TYPE-2 FUZZY SETS

In [7] the formal features of a specific BL-algebra are illustrated in some details. This algebraic structure has shown its usefulness in dealing with several applicative areas [4, 5, 6]. In order to make the paper self-consistent the basic features of the BL-algebra are now briefly recalled.

A *commutative partially ordered monoid* is a structure (L, *, e, ≤) such that (L, *, e) is a *commutative monoid*, where the element e is the unit, ≤ is a *partial order* on L and for all a, b, c, d ∈ L, if a ≤ b and c≤d then a*c ≤ b*d.

An algebra (L,∩, ∪) is a *lattice* if the following identities are true in L:

Idempotency) x∩x = x, x∪x = x

Commutativity) x∩y = y∩x, x∪y = y∩x

Associativity) x∩(y∩z)=(x∩y)∩z, x∪(y∪z)=(x∪y)∪z

Absorption) x∩(x∪y) = x∪(x∩y) = x.

A*residuated lattice* (L,∩, ∩, *, ⇒, e, 0) is a structure such that:

i)(L,∩, ∪, *, ⇒, e, 0) is a lattice with the greatest element e and the least element 0 (with respect to the ordering ≤);
ii) (L,*, e) is a commutative monoid with the unit element e;
iii) * and ⇒ form an adjoint pair, i.e., for all a, b ∈ L, c*a≤b iff c≤a ⇒ b (Galois relation). The binary operation ⇒ on L is called *residuum.*

A residuated lattice(L,∩, ∪, *, ⇒, e, 0) is a *BL-algebra on L* [8, 9] iff the following identities hold for any x,y∈ L:

i) x∩ y = x* (x ⇒ y);

ii) (x ⇒ y) ∪ (y ⇒ x) = e.

Let A be a non empty classical set. A *fuzzy set*s on A [24, 25] is a function s: A --> [0, 1]. If a ∈A then s(a) is said the *membership degree* of a to A.

A *triangular fuzzy number* x=[a, b, c] on [0, 1] is a fuzzy set whose membership function is a triangle whose vertices are the points (a, 0), (b, 1) and (c, 0). In the sequel the following extended operations are used on the class of the [0,1]-triangular fuzzy numbers: i) α*[a,b,c]=[α*a, α*b, α*c] (*product of a real number*); ii) [a, b, c] + [d, e, f] = [a+d, b+e, c+f] (*sum*).

A *type-2 fuzzy set* s_2 [12] on A is a function s_2: A --> $[0, 1]^{[0,1]}$.

Suppose that one has the following objects:

i) **U**: a finite universe of discourse of cardinality p;
ii) **Tr** = {[0, 0, 0], [1, 1, 1]} ∪ {[a, b, c]: {a, b, c} ⊂ [0, 1]}: a set of totally ordered triangular fuzzy numbers. [a, b, c] ≤ [d, e, f] iff a≤d, b≤e, c≤f. It is worth noting that the crisp numbers: [0, 0, 0] and [1, 1, 1] belong to **Tr**;

iii) $\mathbf{F}_2$= {a: $\Sigma_{i:\, m...1,\text{ with } m\leq p}\, x_i/u_i$}: class of the type-2 fuzzy sets **U -->Tr**, where $x_i \in$ **Tr**, $x_i < x_{i+1}$, and {u_m, u_{m-1}, ..., u_1} belongs to the class of crisp partitions ***P*(U)** on **U**. In the sequel the elements $u_i$are called *crisp parts* and the elements x_i *fuzzy parts*

iv) S(U)= {[**0**= [0, 0, 0]/U, (1, 0, 1)], [**1**=[1,1,1]/U, (0, 1, 1)]} ∪ {[a, t]: a ∈$\mathbf{F}_2$, and t=(k, s, a_m, a_{m-1}, ..., a_1) is a suitable t-uple of positive integers, that satisfies the following constraints: *j)* if k= 1 then a_i=1 for any i:1...m; *jj)* if k>1 the t-uple (a_m, a_{m-1}, ..., a_1) is symmetric with respect to the central values }; *jjj)* s = 0 for **0**, instead s=1 for any A ≠ **0** and **1** in**S(U)**. Moreover (k, s, a_m, ..., a_1) = (1, s, 1, 1, ..., 1) iff the related type-2 fuzzy set is not the product of other sets through the operation ◊ introduced in the sequel.

One can give the following intuitive meaning: the type-2 fuzzy set $\Sigma_{i:\, m...1,\text{ with } m\leq p}\, x_i/u_i$ represents an *attribute* A in the sense that the elements $u_i \subseteq$**U** *satisfy* A with strength x_i. Moreover, one says that the elements of U are *classified* with respect to A by means of the linguistic terms represented by the type-1 fuzzy sets $x_i \in [0,1]^{[0,1]}$. With this interpretation the element **0** and **1** are read as "*No information*" and "*Not compatible*", respectively. The label standing for "*No information*" is utilized when there is no information available about the elements in U in order to assess the degree they satisfy the attribute A with, whereas "*Not compatible*" is used if the elements in U are not compatible with the property A.

Given
A=[$\Sigma_{i:\, n\leq p...1}\, x_i/u_i$, ($k_A$, s_A, a_n, a_{n-1}, ..., a_1)] and
B=[$\Sigma_{i:\, m\leq p...1}\, y_i/v_i$, ($k_B$, s_B, b_m, b_{m-1}, .., b_1)]∈**S(U)**,
the binary operation ◊on **S(U)**x**S(U)** is defined as follows:

$$\mathbf{A \lozenge B = [\Sigma_{i:n+m-1...1} z_i/w_i,\ (k_{A+}k_B,\ 1,\ c_{n+m-1}, ..., c_1)]}$$

where

$$w_i = \bigcup_{\substack{h=1...i \\ k=i...1 \\ h\leq n, k\leq m}} (u_h \cap v_k$$

fuzzy parts

$$z_i = \frac{s_A s_B}{(k_A + k_B)c_i} \sum_{\substack{h=1...i \\ k=i...1 \\ h\leq n, k\leq m}} a_h b_k (k_A x_h + k_B y_k$$

$$c_i = \sum_{\substack{h=1...i \\ k=i...1 \\ h\leq n, k\leq m}} a_h b_k$$

crisp parts

It is worth noting that A ◊ **0** = **0** and A ◊ **1** = A.

The indices a_h e b_k represent the number of sets that have generated the i-th class of A and B, respectively. The indices k_A e k_B represent, in turn, the number of sets that have generated the classes of A and B, respectively. The quantities $\mathbf{s_A}$ and $\mathbf{s_B}$ assume the values 1 for any attribute ≠ **0** and **1** in **S(U)**. The operation for z_i represents essentially a mean among the type-2 fuzzy sets, where each fuzzy set takes a weight in some way related to the changes induced by the composition. Essentially these indices include the computational history of the type-2 fuzzy sets. The operation ◊ is well defined: *i*) (w_{n+m-1}, w_{n+m-2} ..., w_1) ∈***P*(U)**; *ii*) the t-uple (c_{m+n-1}, ..., c_1) is strictly increasing and symmetric with respect to the central values; *iii)* A◊B∈**S**(U); *iv*) the elements z_i are triangular fuzzy numbers on [0, 1].
The algebraic properties of the structure have been widely investigated and the reader is referred to [7] where a comprehensive example is illustrated in details.

4. ALGEBRAIC APPROACH TO FUZZY SCREENING

The algebraic approach to fuzzy screening is very simple, as representing any knowledge base related to a screening problem is immediate and standard. Moreover, the method has a general validity as the algebraic computation to be carried out on type-2 fuzzy sets is always the same. In this approach the critical part is the meaning function that maps the linguistic terms of the problem onto the corresponding triangular numbers. No formal indication is given by the algorithms based on linguistic terms. One just requires that the triangular fuzzy numbers be totally ordered.

The parameters involved are: *criteria*, *weights*, *solutions* and *rules of aggregation*.
Criteria and goals in this approach are strings, i.e. type-2 fuzzy sets. The weights associated to the criteria are mere numerical quantities that have to obey only the constraint of their positivity (w>0).
The *solutions* singled out by the algorithm are represented as follows: $[a]^\alpha$ $[b]^\beta$. Thus they are formed by strings of criteria associated with fuzzy linguistic labels (α and β). The solution is a term of a linguistic variable, since for each attribute its linguistic rating is singled out.
The *rule of aggregation* is represented by the operation ◊. The new string generated by the monoidal composition contains a finer classification of the original strings and takes into account all the criteria and constraints to be satisfied.

The algebraic method for screening can be summarized as follows:

1) The universe of discourse is given.
2) The attributes are selected.
3) The linguistic terms are selected.
4) The (totally ordered) triangular fuzzy numbers representing the linguistic terms are singled out.
5) If necessary, the weights are introduced.
6) The strings (type-2 fuzzy sets) are constructed.
7) The strings are composed.
8) The results are interpreted.

In case the results are not acceptable the method is applied again, with different choices, starting from either step 3 or step 4.
Translating Yager's model into the language of the algebraic structure is immediate. In fact the set of possible alternatives X corresponds to the universe U in the fuzzy structure. The collection of criteria C corresponds to the fuzzy set of attributes. The scale of values S corresponds to the set E of fuzzy numbers representing the linguistic labels. Moreover Yager's method induces repeated changes in the set of solutions X and the importance associated with the criteria, the same happens in this approach as the procedure involves changes in the universe U and the weights associated with the attributes.

5. A CASE STUDY

Consider the problem of assigning an executive position within a manufacturing company. A scale with seven valuesis used and the process essentially involves three components:

I. a set of candidates for the position (set of alternatives)
II. a set of criteria relevant for singling out the best candidate
III. a panel (group of experts) that rates the candidates

In this case study, one has six candidates and the panel includes three experts. The criteria are shown in Table 5.1:

Criteria	Description	Importance
C_1	Graduating marks in Engineering	5
C_2	Marks in Master of Engineeering or Economics	4
C_3	5 years experience in manufacturing companies	5
C_4	Expertise shown in manufacturing area	3
C_5	Skills in executive positions	5
C_6	Development of collaborations with government	4

Table 5.1

The decision process is split into two phases. In the first phase each component of the panel rates the candidates according to the criteria. The scale of values is **S**: *Perfect* (P), *Very High* (VH), *High* (H), *Medium* (M), *Low* (L), *Very Low* (VL), *None* (N), and the related indices are Si (i=1…7).

The following tables summarize the experts ratings. With C_j is denoted the j-th criterion and with X_i the i-th candidate.
The ratings expressed by the first expert are reported in Table 5.2:

	C1	C2	C3	C4	C5	C6
X_{11}	VH	M	H	N	VH	M
X_{21}	M	N	H	L	M	H
X_{31}	P	H	VH	M	VH	VH
X_{41}	H	H	VH	L	VH	H
X_{51}	VH	P	L	VH	P	H
X_{61}	M	P	M	H	H	L

Table 5.2

Tables 5.3 and 5.4 report the ratings of the second and third expert, respectively.

	C1	C2	C3	C4	C5	C6
X_{11}	H	M	H	N	VH	L
X_{21}	L	M	VH	M	M	M
X_{31}	P	L	VH	VH	P	H
X_{41}	VH	VH	P	VH	VH	VH
X_{51}	H	H	L	M	M	P
X_{61}	H	VH	N	L	H	N

Table 5.3

	C1	C2	C3	C4	C5	C6
X_{13}	H	M	P	VL	P	M
X_{23}	L	L	VH	VL	M	N
X_{33}	P	H	H	VH	H	P
X_{43}	VH	H	VH	L	M	P
X_{53}	H	H	VL	VL	N	VH
X_{63}	VH	M	VL	L	H	VL

Table 5.4

6. APPLYING YAGER'S METHOD

One has:

- $X = \{ X_1, \ldots, X_6 \}$ is the set of candidates
- The set of experts is denoted by $A = \{ A_1, A_2, A_3 \}$.
- The criteria are denoted by $C = \{ C_1, \ldots, C_6 \}$ and their importance is shown in Table 5.1.

The importance of the criteria has to be expressed in terms of the scale of values S. To each weight i corresponds the value S_i with $i = 1,\ldots,7$, and thus one has: $I(C_1) = H$, $I(C_2) = M$, $I(C_3) = H$, $I(C_4) = L$, $I(C_5) = H$, $I(C_6) = M$. X_{ik} corresponds to the rating of the k-th expert for the i-th candidate. Moreover, $Neg(S_i)) = S_{8-i.}$

Thus for the first expert and the first candidate one has:

X11 = min [Neg(Imp(C1)) $\vee$ X11 (C1) , Neg(Imp(C2)) $\vee$ X11 (C2), Neg(Imp(C3)) $\vee$ X11 (C3) , Neg(Imp(C4)) $\vee$ X11 (C4), Neg(Imp(C5)) $\vee$ X11 (C5) , Neg(Imp(C6)) $\vee$ X11 (C6)] =

= min [Neg(H) $\vee$ VH , Neg(M) $\vee$ M , Neg(H) $\vee$ H , Neg(L) $\vee$ N , Neg(H) $\vee$ VH , Neg(M) $\vee$ M] =

= min [L $\vee$ VH , M $\vee$M , L $\vee$ H , H $\vee$ N , L $\vee$ VH , M $\vee$ M] =min [VH , M , H , H , VH , M] = M.

By iterating one gets the final ratings of the first expert:

X11 = M , X21 = M , X31 = H , X41 = H , X51 = L , X61 = M .

In a similar way the ratings of the second and third expert are computed:

X12 = M , X22 = L , X32 = M , X42 = VH , X52 = L , X62 = L .

X13 = M , X23 = L , X33 = H , X43 = M , X53 = VL , X63 = L .

In the second step of the decision process, the ratings of the expert are suitably combined. In this example one has r=3 (number of experts), q=7 (number of elements in S), and thus one has the following values of Q: $Q(0) = S_1$, $Q(1) = S_3$, $Q(2) = S_5$, $Q(3) = S_7$

With i=1 for the first alternative one gets: $X_{11} = M$, $X_{12} = M$, $X_{13} = M$, whereas the values for B_j are: $B_1 = M$, $B_2 = M$, $B_3 = M$. Thus the rating of the first alternative is:

$X_1 = \max_{j=1,\ldots,3} [\, Q(j) \wedge B_j] = \max [\, Q(1) \wedge B_1, Q(2) \wedge B_2, Q(3) \wedge B_3] = \max [\, S_3 \wedge M, S_5 \wedge M, S_7 \wedge M] = \max [\, L \wedge M, H \wedge M, P \wedge M] = \max [\, L, M, M] = M$.

The ratings of all alternatives are:
$X_1 = M$, $X_2 = L$, $X_3 = H$, $X_4 = H$, $X_5 = L$, $X_6 = L$.

The candidates X_3 and X_4 are singled out thanks to the rating H, but one is unable to select one candidate, although in the first and third tables the candidate X_3 presents better ratings.

7. APPLYING THE FUZZY ALGEBRAIC METHOD

From the formal point of view one has::

- The universe U is the set of candidates { $X_1, X_2, X_3, X_4, X_5, X_6$ };
- The set of attributes is the set of criteria
- The fuzzy set E representing the linguistic labels is:
-

P (*Perfect*) = [0.9 , 1 , 1] VH (*Very High*)= [0.8 , 0.8 , 0.9] H (*High*)= [0.6 , 0.7 , 0.7] M (*Medium*) = [0.4 , 0.5 , 0.6]	L (*Low*) = [0.2 , 0.3 , 0.3] VL (Very *Low*) = [0.1 , 0.2 , 0.3] N (*None)* = [0 , 0 , 0.2]

- The following weights are assigned to the criteria:
  $w_{C1}=3$; $w_{C2}=4$; $w_{C3}=3$; $w_{C4}=5$; $w_{C5}=3$; $w_{C6}=4$;
  The weights stem from Table 5.1 and from the fact that Yager in the formula for the rating uses $Neg(Imp_k(C_i))$ namely the symmetrical element in the scale S of the importance given to the criterion by the expert.
- The strings obtained from Table 5.2 are:

$C_{11}=[X_3]^P [X_1,X_5]^{VH} [X_4]^H, [X_2,X_6]^M$	$C_{41}=[X_5]^{VH}, [X_6]^H, [X_3]^M, [X_2,X_4]^L, [X_1]^N$
$C_{21}=[X_5,X_6]^P, [X_3,X_4]^H, [X_1]^M, [X_2]^N$	$C_{51}=[X_5]^P, [X_3,X_4,X_1]^{VH}, [X_6]^H, [X_2]^M$
$C_{31}=[X_3,X_4]^{VH}, [X_1,X_2]^H, [X_6]^M, [X_5]^L$	$C_{61}=[X_3]^{VH}, [X_2,X_4,X_5]^H, [X_1]^M, [X_6]^L$

These strings can be combined according to the weights of each criterion and so one gets the rating given by the first expert:

$$Exp1= [X_5]^{B[VH]} [X_3]^{IB[H,VH]} [X_4, X_6]^{ib(M,H)} [X_1]^{NT[M]} [X_2]^{b[M]};$$

A similar reasoning for the other two experts leads to the respective ratings:

$$Exp2= [X_4]^{nt[VH]} [X_3]^{ib[H,VH]}, [X_5]^{ib(M,H)} [X_2]^{M} [X_1,X_6]^{b[M]};$$
$$Exp3= [X_3]^{VH} [X_4] H [X_1]^{ib(M,H)} [X_5,X_6]^{b[M]} [X_2]^{nt[L]};$$

Now one can say that for the generic element X_i of the universe the final rating is given by $X_i = \max_{j=1,2,3} [\, Q(j) \wedge B_j]$ where B_j is the j-th highest value among those associated by the experts to alternative X_i in the three above-mentioned strings. For example, one has for X_1 :

$X_1 = \max_{j=1,2,3} [\, Q(j) \wedge B_j] = \max [\, S_3 \wedge ib(M,H), S_5 \wedge nt(M), S_7 \wedge b(M)] = \max [L \wedge ib(M,H), H \wedge nt(M), P \wedge b(M)] = \max [\, L, nt(M), b(M)] = nt(M)$

This value is similar to that obtained by Yager. For the other alternatives one obtains $X_2 = b(M)$.

8. CONCLUDING REMARKS

It is worth noting that the rating of the alternative X_2 given by the first expert is b(M) and agrees with Yager's result. The result X_{22} = L by Yager's is not suitable whereas now X_{22} =M obtained from the string Exp2 is suitable according to Table 5.3. The rating X_{23} =L by Yager and ours X_{23} =nt(L) thus agree and the latter is more justified than Yager's. Thus one has:

X_3 =ib(H,VH)

X_4 =H (same result by Yager's)

X_5 =ib(M,H) (reasoning in a similar way to X_2 this result is more reasonable)

X_6 =b(M) also in this case it is worth noting that the ratings of this element given by the first expert agree with Yager's whereas ours are more suitable for the other two experts

The algebraic approach allows us to screen the results by emphasizing the alternative X_3 whose ratings are consistently better than X_4 in two tables out of three.

Ratings of alternatives play a central role in screening problems. In the algebraic approach ratings can be easily represented by type 2 fuzzy sets and thus by the basic elements of the BL-algebra. Taking this fact as starting point, the structure represents an effective and viable tool in tackling screening problems. It is worth noting that if ratings are expressed in linguistic terms the solution to the problem is easily attained by this approach. In case ratings are expressed by fuzzy numbers or usual numbers satisfactory results can be achieved by suitably "*tuning*" the linguistic labels.

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10. REFERENCES

[1] Brock G.N., Beavis W.D., Kubatko L.S.: Fuzzy Logic and Related Methods as a Screening Tool for Detecting Gene Regulatory Networks. Information Fusion, 10(3), pp.250-259, 2009
[2] Carlsson C., Fuller R.: On Fuzzy Screening Systems EUFIT'95 Conf., Aachen, pp.1261-1264, 1995
[3] Chattopadhyay S., Pratihar D.K., De Sarkar S.C.: Fuzzy-Logic-Based Screening and Prediction of Adult Psychoses: A Novel Approach, IEEE Transactions on Systems, Man, and Cybernetics, Part A, 39(2), pp.381-387, 2009
[4] Di Lascio L, Fischetti E., Gisolfi A.: "A Fuzzy Based Method for Environmental Evaluation". Proc. IASK International Conference E-Activity and Leading Technologies, Madrid, pp.17-22, 2008
[5] Di Lascio L., Fischetti E., Gisolfi A., Loia V., Nappi A., "Linguistic Resources and Fuzzy Algebraic Computing in Adaptive Hypermedia Systems", E.Damiani, L.Jain (Eds.), Soft Computing and Software Engineering, pp.274-312, 2004
[6] Di Lascio L., Fischetti E., Gisolfi A., Nappi A.: Type-2 Fuzzy Decision Making by means of a BL-algebra, IEEE Int. Conf. Fuzzy Systems, pp.1-6, 2007
[7] Fischetti, E.: "A BL-Algebra on Type-2 Fuzzy Sets", Asian J. of Fuzzy and Applied Mathematics, 1, 1, pp.12-20, 2013
[8] Hájek P.: "Basic fuzzy logic and BL-algebras" Soft Comput. 2(3), pp.124-128, 1998
[9] Lele C.: "Algorithms and Computations in BL-Algebras", Int. J. Artificial Life Research, 1, 4, pp.29-47, 2010
[10] Liginlal D., Ram S., Duckstein L.: Fuzzy measure theoretical approach to screening product innovations, IEEE Transactions on Systems, Man, and Cybernetics, Part A, 36(3), pp.577-591, 2006
[11] Malczewski,J.:Fuzzy Screening for Land Suitability Analysis, Geographic Environmental Modelling, 6,1,pp.27-39, 2002
[12] Mendel, J. M., John R.I.: "Type-2 Fuzzy Sets Made Simple", IEEE Trans. on Fuzzy Systems, vol. 10, pp. 117-127, 2002.
[13] Ozyer T., Alhajj R., Barker K.: Intrusion detection by integrating boosting genetic fuzzy classifier and data mining criteria for rule pre-screening, Int. J. Approximate Reasoning, 49 (2), pp.451-465, 2008
[14] Paetz J., Schneider G.: A neuro-fuzzy approach to virtual screening in molecular bioinformatics. Fuzzy Sets and Systems, 152(1), pp.67-82, 2005
[15] Pal D., Mandana K.M., Pal S., Sarkar D., Chackraborty C:: Fuzzy expert system approach for coronary artery disease screening using clinical parameters, Knowledge-Based Systems, 36, pp.162-174, 2012
[16] Pham t.d., Tran D.T., Zhou X.: Fuzzy information fusion of classification models for high-throughput image screening of cancer cells in time-lapse microscopy, KES Journal, 11 (4), pp.237-246, 2007
[17] Smimou K., Bhatt S., Dahl D.W.: Fuzzy analytical hierarchy process in new product screening, EUSFLAT Conference, pp.89-92, 2001

[18] Yager R.R.: Fuzzy Screening Systems,in R. Lowen& M. Roubens (eds.) Fuzzy Logic: State of the Art, Kluwer, pp. 251-261, 1993

[19] Wang J., Zhou X., Li F., Bradley P., Chang S., Perrimon N., Wong S.: An image score inference system for RNAi genome wide screening, J. Biomedical Informatics, 42 (1), pp.32-40, 2009

[20] Wang M.L., Wang H.F., Lin C.L.: Ranking fuzzy numbers based on lexicographic screening procedure, Int. J. Informations Technology and Decision Making, 4 (4), pp.663-678, 2005

[21] Wang Y., Chin K.: A linear goal programming priority method for fuzzy analytic hierarchy process and its applications in new product screening, Int. J. Approximate Reasoning, 49 (2), pp.451-465, 2008

[22] Wibowo S., Deng H.: A fuzzy rule-based approach for screening international distribution centres, Computers and Mathematics with Applications, 64 (5), pp.1084-1092, 2012

[23] Wong W.K., Zeng X.H., Au W.M.R., Mok P.Y., Leung S.Y.S.: A fashion mix-and-match expert system for fashion retailers using fuzzy screening approach. Expert Syst. Appl., 36(2), pp.1750-1764, 2009

[24] Zadeh L.A.: “Fuzzy Sets”, Information and Control, 8(3), pp.338-353, 1965

[25] Zadeh L.A., “The Concept of a Linguistic Variable and its Application to Approximate Reasoning”, I, II, III. Information Sciences I 8 – II 8 – III 9. pp 199-249 ; pp 301-357; pp 43-80, 1975