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Polish-Finnish Symposium
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# APPLICATION OF INTERACTIVE SOLUTIONS FOR DECISION SUPPORT IN BARGAINING PROBLEM, AN ILLUSTRATIVE EXAMPLE

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ABSTRACT

The paper relates to a problem of making collective decision in the case of multicriteria bargaining. An illustrative example is presented of an interactive procedure facilitating two players in analysis of their bargaining situations and in finding compromise solution according to their preferences. The example has been made with use of the MC-BARG system elaborated by the authors.

Key words: decision support systems, making collective decision, multicriteria optimization.

## 1. INTRODUCTION

A multicriteria bargaining problem has been considered in papers [1], [2], [3] as a generalization of the classical problem considered in [4], under the assumption that the players have not explicitly given utility functions defined on their objectives. In this case an interactive solution concept has been proposed as a base for an interactive procedure supporting the players in finding an efficient solution according to their preferences.

In this paper an illustrative example is given presenting how the procedure can be used and can lead the players to a cooperative solution. The example has been prepared using the decision support system MC-BARG described in [5]. This paper is recommended to be read together with [3] in which the interactive procedure is presented in details.

## 2. AN EXAMPLE OF A BARGAINING PROBLEM

The exemplary bargaining problem relates to the cooperation of two farms. The farm owners try to maximize production of the agricultural products and to minimize inputs for the production under constraints related to the conditions of the production and applied technologies. The following two situations can be considered. In the first one each owner acts independently, that is, he does not plan his production with the other. In this case, having a model of the production, to formulate his production plan according to his preferences, he can use, as a supporting tool, one of the multiobjective optimization packages. In the second situation, the owners decide to cooperate. Typically, in such a case, some surplus is obtained in comparison to the first case. It is a result of scale effects and of better utilization of production inputs. Assuming cooperation, the farm owners have to then decide and agree how to allocate the surplus between them. They would like to take into account their preferences on the objectives which can be, in a general case, different, and also they would like to make the division having a feeling of fairness. In this case a solution obtained by the owners in the first case, called further a status quo point, becomes a starting point for negotiation on the surplus division. This is an example of the bargaining problem called AGRICO model you can support with the MC-BARG system. In the model each of two players (farm owners) has three objectives, namely: milk production, rye production, and savings of tractor power. The model is formally described by the status quo point and by an agreement set. The agreement set has in the case interpretation of the surplus that can be obtained and divided between the players in the case of cooperation. The set can be described by a system of inequalities in the objective space of the players. For this experiment, denoting the objectives: a1, a2, a3 for the first player, and b1, b2, b3 for the second one, respectively, the agreement set is described by the set of following constraints:

$a1, a2, a3, b1, b2, b3 \geq 0;$

$14 - (a1 + b1)^{1/2} - a2 - b2 \geq 0;$

$17 - (a1 + b1)^{1/2} - a3 - b3 \geq 0;$

$6 - a2 \geq 0;$

$8 - a3 \geq 0;$

$8 - b2 \geq 0;$

$9 - b3 \geq 0;$

This arbitrary model is relatively simple, however the resulting bargaining problem is not trivial, and features of the interactive procedure can be presented with the model The system MC-BARG has a built-in model editor which allows introducing the model into the system.

## 3. INTERACTIVE SOLUTION OF THE PROBLEM

To solve the problem described in section 2 one needs to follow a certain mediation procedure [3].

At the start of the procedure the farm owners (player A and player B) have information about the outcome they can reach acting independently (i.e. the status quo of the bargaining problem). Next they start to make some moves in order to achieve an nondominated solution, acceptable for both of them. This is done in several rounds. At each round each player has to specify his preferable improvement direction which will be taken into account while calculating this round's cooperative solution. Obviously, the player can think about a certain number of improvement directions but only one of them can be chosen. To facilitate the task of choosing the player improvement direction the MC-BARG offers a special option, so called the TEST DIRECTION option. Using this option the player can compare several different improvement directions which are possible at any given stage of the procedure before deciding on one of them.

The proposed method assumes that the players have limited confidence in their ability to predict consequences and possible outcomes. This is expressed using the concept of the confidence coefficient. At the beginning the system assumes the value of this coefficient equal to 1. The player can change it to any value greater than 0 and lower than 1. A lower value of the confidence coefficient means that the player has more limited confidence on the future outcomes of the game and results in a greater number of iterations in the mediation procedure. A value equal to 1 means that the cooperative solution has to be found in one round.

As an example let's show how the system can help player A in taking a decision about his first move (Figure 1 and 2). The three objectives of this player include milk production, rye production and saving of tractor power. After selecting the TEST DIRECTION option player A gets the information shown in Figure 1 as variant 1 (the variant corresponds to the number of a trial). This includes: the status quo, the reference point, the solution, the maximal confidence coefficient, the one-shot solution, the RA-utopia point and the ideal point. This first variant is generated by the system and is called the neutral solution. The status quo value is specified at the model formulation phase (see [3],[5]). The first reference point is assumed to be equal to the value of the ideal point. The purpose of this variant is to show some information about the player's possibilities. The status quo and the ideal points define reasonable bounds for the reference points defined by the player in his own analysis. The RA-utopia point describes the outcome the player can obtain under an assumption that the counter player will obtain his outcome at the level of his status quo. The one-shot solution is the outcome the player can obtain on the basis of the proposed mediation solution concept [1], under the assumption that an efficient solution is reached in one round. The maximal confidence coefficient defines the lower limit of the confidence coefficient for which the efficient solution is reached in one round.

Now the system is ready to assist player A in his unilateral analysis. Within this analysis the status quo and the ideal point values are constant, while the other values depend on the confidence coefficient and the reference point specified by the player.

Let player A assume the confidence coefficient value to be 0.3. Now for any reference point defined by the player, MC-BARG will generate the value of the corresponding tentative solution. An example of the analysis performed by this player with the help of the MC-BARG is shown in Figure 2. The player's preferences are to obtain first of all more milk and to save more tractor power. As the reference points he specifies then values equal to the ideal point for milk production and for the savings of tractor power ( 113.00 and 8.00, respectively), and a value lower than the ideal point for rye production (4.00). These values together with the corresponding solution are shown as variant 2. Next he wants to test the outcome to be obtained while decreasing the milk (100.00) and rye production (3.00). This variant has number 3. All of the solutions can also be displayed in graphical form, as shown in Figure 3.

The player can continue his tests until he finds his preferable improvement direction.

Let us assume that the decrease of the rye production in the third variant seems to be too high for the player, so he selects the second variant as the best. This reference point will be taken to the further computations.

The same kind of assistance can be given to the second player. Player B's tests are shown in Figure 4. This player has more limited confidence than the first one so he assumes the confidence coefficient equal to 0.2. He also decides to make more tests (the number of trials is indefinite however, only three of them can be shown on the screen. The special option of

MC-BARG allows the player to choose the variants he wants to be shown at the given moment). The player tests 4 variants. Having in mind an increase in rye production and in the savings of tractor power, the player decides to select the fourth variant.

Having the preferable improvement directions for the both of the players selected, the cooperative solution can be calculated for the first iteration. The players can see the obtained values for the particular objectives using the REPORT option of the MC-BARG system (Fig.9,10).

The players can accept this solution as a final one or consider it to be only a temporary solution and a starting point for the next iteration. In this case the procedure is continued. It has been shown in [2],[3] that the procedure is well-defined and converges to the strongly Pareto optimal point in the agreement set.

Let us assume that the players decided to continue the process of bargainging. In that case the cooperative (agreement) solution obtained at the first iteration becomes the status quo used at the second iteration, the players select their new preferable improvement directons together with their confidence coefficient and based on that the MC-BARG calculates a new cooperative solution.

The analysis done by the first and the second player is presented in Figures 5 and 6. The solution of the first round is now in the column of the status quo. It strictly dominates the status quo of the game (see Figure 3 and 4) and is calculated along the improvement direction defined by the preferable reference point selected in the first iteration. We can observe the decrease of the set of agreement outcomes dominating the new status quo for both of the players (i.e. the values of the ideal point are smaller than those in the previous iteration).

In the second iteration both of the players assume the confidence coefficient equal to 0.3.

The first player tries, as previously, to increase the milk production and savings of tractor power - in the second variant and to slightly increase rye production - in the third variant. The obtained increase in the rye production is very small for a relatively significant decrease in the savings of tractor power so the player decides to select the second variant as the best.

The second player (Fig.6) tries to increase rye production. From the tested variants he selects the fourth one as the best.

Now the MC-BARG computes the next cooperative solution (Fig.9,10). This is still not a strongly Pareto optimal solution so the players decide to continue, e.g. to make one iteration more. This should be the final iteration so they decide to give the value 1 to the confidence coefficient. The interactive analysis performed by the players is presented in Figures 7 and 8.

Both the players assume the confidence coefficients as equal to 1.0. That means they decide to have relatively high confidence in the future outcomes and to not prolong the procedure to the next iteration. The first player tries consistently to increase milk production but not at the cost of too high a decrease in rye production. So he decides to select the second variant as the best. The second player interested in increasing rye production selects the third variant as the preferable one.

Next the MC-BARG calculates the new agreement solution. This is the final, efficient solution. The players can see the obtained values from the report shown in Figures 9 and 10. They can observe values of the agreement points in the successive iterations. The values are also presented in graphical form as compared to the initial status quo point. The iteration numbers in the bars indicate the values. The values obtained at the last, third iteration are equal to the one-shot solution. This means the final, efficient solution (on the Pareto frontier) in the agreement set has been reached.

## 4. FINAL REMARKS

An illustration is given in this paper on how the interactive solution concept utilised in an interactive procedure can be used for decision support in multicriteria bargaining. In the example the players had different preferences on their objectives. The results obtained in particular rounds relate to the preferences. The procedure converged after three iterations. The reference points approach used for testing different improvement directions worked efficiently and the players could easily find and select their preferable directions in the particular rounds.

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TEST IMPROVEMENT DIRECTIONS          Player no 1          Iteration no 1

INFO    CONF_COEF    NEW_REF    SELECT    GRAPH    SCROLL_CRIT    SCROLL_VAR    EXIT

Your confidence coefficient : 1.0000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | [th liters] | | | |
| 1 | 20.40 | 113.00 | 42.10 | 0.50 | 42.10 | 63.79 | 113.00 |
| | RYE | PRODUCTION | | [th tonnes] | | | |
| 1 | 0.60 | 5.43 | 1.73 | 0.50 | 1.73 | 2.86 | 5.43 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 0.00 | 8.00 | 1.87 | 0.50 | 1.87 | 3.75 | 8.00 |

Figure 1

TEST IMPROVEMENT DIRECTIONS Player no 1 Iteration no 1

INFO CONF_COEF NEW_REF SELECT GRAPH SCROLL_CRIT SCROLL_VAR EXIT

Your confidence coefficient : 0.3000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | | [th liters] | | |
| 1 | 20.40 | 113.00 | 33.42 | 0.50 | 42.10 | 63.79 | 113.00 |
| 2 | 20.40 | 113.00 | 35.73 | 0.50 | 45.94 | 71.49 | 113.00 |
| 3 | 20.40 | 100.00 | 37.00 | 0.50 | 48.04 | 75.74 | 113.00 |
| | RYE | PRODUCTION | | | [th tonnes] | | |
| 1 | 0.60 | 5.43 | 1.28 | 0.50 | 1.73 | 2.86 | 5.43 |
| 2 | 0.60 | 4.00 | 1.16 | 0.50 | 1.54 | 2.48 | 5.43 |
| 3 | 0.60 | 3.00 | 1.10 | 0.50 | 1.43 | 2.27 | 5.43 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 0.00 | 8.00 | 1.12 | 0.50 | 1.87 | 3.75 | 8.00 |
| 2 | 0.00 | 8.00 | 1.32 | 0.50 | 2.21 | 4.41 | 8.00 |
| 3 | 0.00 | 8.00 | 1.67 | 0.50 | 2.78 | 5.56 | 8.00 |

Figure 2

TEST IMPROVEMENT DIRECTIONS Player no 1 Iteration no 1

INFO CONF_COEF NEW_REF SELECT GRAPH SCROLL_CRIT SCROLL_VAR EXIT

Your confidence coefficient : 0.3000

| Var | Status quo | Reference point | Solution | Graphical representation of solutions |
|---|---|---|---|---|
| | MILK | PRODUCTION | | [th liters] |
| 1 | 20.40 | 113.00 | 33.42 |  |
| 2 | 20.40 | 113.00 | 35.73 | |
| 3 | 20.40 | 100.00 | 37.00 | |
| | RYE | PRODUCTION | | [th tonnes] |
| 1 | 0.60 | 5.43 | 1.28 |  |
| 2 | 0.60 | 4.00 | 1.16 | |
| 3 | 0.60 | 3.00 | 1.10 | |
| | SAVINGS OF | TRACTOR | POWER | [th tractor hours] |
| 1 | 0.00 | 8.00 | 1.12 |  |
| 2 | 0.00 | 8.00 | 1.32 | |
| 3 | 0.00 | 8.00 | 1.67 | |

Figure 3

TEST IMPROVEMENT DIRECTIONS      Player no 2      Iteration no 1

INFO   CONF_COEF   NEW_REF   SELECT   GRAPH   SCROLL_CRIT   SCROLL_VAR   EXIT

Your confidence coefficient :   0.2000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | | [th liters] | | |
| 1 | 31.00 | 123.60 | 39.68 | 0.50 | 52.70 | 74.39 | 123.60 |
| 2 | 31.00 | 70.00 | 36.18 | 0.50 | 43.92 | 56.90 | 123.60 |
| 4 | 31.00 | 60.00 | 35.19 | 0.50 | 41.44 | 51.97 | 123.60 |
| | RYE | PRODUCTION | | | [th tonnes] | | |
| 1 | 1.40 | 6.23 | 1.85 | 0.50 | 2.53 | 3.66 | 6.23 |
| 2 | 1.40 | 6.23 | 2.04 | 0.50 | 3.00 | 4.61 | 6.23 |
| 4 | 1.40 | 6.23 | 2.10 | 0.50 | 3.14 | 4.89 | 6.23 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 0.00 | 9.00 | 0.84 | 0.50 | 2.11 | 4.22 | 9.00 |
| 2 | 0.00 | 9.00 | 1.20 | 0.50 | 2.98 | 5.98 | 9.00 |
| 4 | 0.00 | 8.00 | 1.16 | 0.50 | 2.88 | 5.79 | 9.00 |

Figure 4

TEST IMPROVEMENT DIRECTIONS    Player no 1    Iteration no 2

INFO    CONF_COEF    NEW_REF    SELECT    GRAPH    SCROLL_CRIT    SCROLL_VAR    EXIT

Your confidence coefficient :    0.3000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | | [th liters] | | |
| 1 | 30.62 | 84.19 | 38.36 | 0.50 | 43.48 | 56.42 | 84.19 |
| 2 | 30.62 | 84.19 | 39.63 | 0.50 | 45.58 | 60.66 | 84.19 |
| 3 | 30.62 | 80.00 | 39.32 | 0.50 | 45.06 | 59.62 | 84.19 |
| | RYE | PRODUCTION | | | [th tonnes] | | |
| 1 | 0.98 | 3.79 | 1.38 | 0.50 | 1.65 | 2.33 | 3.79 |
| 2 | 0.98 | 3.00 | 1.32 | 0.50 | 1.54 | 2.11 | 3.79 |
| 3 | 0.98 | 3.00 | 1.33 | 0.50 | 1.57 | 2.16 | 3.79 |
| | SAVINGS OF | TRACTOR POWER | | [th tractor | hours] | | |
| 1 | 0.88 | 7.73 | 1.87 | 0.50 | 2.53 | 4.18 | 7.73 |
| 2 | 0.88 | 7.73 | 2.03 | 0.50 | 2.79 | 4.72 | 7.73 |
| 3 | 0.88 | 6.00 | 1.78 | 0.50 | 2.38 | 3.89 | 7.73 |

Figure 5

TEST IMPROVEMENT DIRECTIONS        Player no 2   Iteration no 2

INFO   CONF_COEF   NEW_REF   SELECT   GRAPH   SCROLL_CRIT   SCROLL_VAR   EXIT

Your confidence coefficient :    0.3000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | [th liters] | | | |
| 1 | 35.19 | 88.76 | 42.93 | 0.50 | 48.09 | 60.99 | 88.76 |
| 2 | 35.19 | 70.00 | 41.18 | 0.50 | 45.16 | 55.16 | 88.76 |
| 4 | 35.19 | 60.00 | 40.01 | 0.50 | 43.20 | 51.25 | 88.76 |
| | RYE | PRODUCTION | | [th tonnes] | | | |
| 1 | 2.10 | 4.91 | 2.51 | 0.50 | 2.78 | 3.45 | 4.91 |
| 2 | 2.10 | 5.00 | 2.60 | 0.50 | 2.93 | 3.76 | 4.91 |
| 4 | 2.10 | 5.00 | 2.66 | 0.50 | 3.03 | 3.98 | 4.91 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 1.16 | 8.00 | 2.15 | 0.50 | 2.81 | 4.45 | 8.00 |
| 2 | 1.16 | 8.00 | 2.33 | 0.50 | 3.12 | 5.08 | 8.00 |
| 4 | 1.16 | 6.00 | 2.10 | 0.50 | 2.72 | 4.29 | 8.00 |

Figure 6

TEST IMPROVEMENT DIRECTIONS    Player no 1    Iteration no 3

INFO    CONF_COEF    NEW_REF    SELECT    GRAPH    SCROLL_CRIT    SCROLL_VAR    EXIT

Your confidence coefficient :    1.0000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK | PRODUCTION | | | [th liters] | | |
| 1 | 39.63 | 60.43 | 44.75 | 0.50 | 44.75 | 49.88 | 60.43 |
| 2 | 39.63 | 60.00 | 45.89 | 0.50 | 45.89 | 52.17 | 60.43 |
| 3 | 39.63 | 60.00 | 47.96 | 0.52 | 47.96 | 55.52 | 60.43 |
| | RYE | PRODUCTION | | | [th tonnes] | | |
| 1 | 1.32 | 2.41 | 1.59 | 0.50 | 1.59 | 1.86 | 2.41 |
| 2 | 1.32 | 2.00 | 1.53 | 0.50 | 1.53 | 1.74 | 2.41 |
| 3 | 1.32 | 1.50 | 1.39 | 0.52 | 1.39 | 1.46 | 2.41 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 2.03 | 5.98 | 3.01 | 0.50 | 3.01 | 3.98 | 5.98 |
| 2 | 2.03 | 6.00 | 3.25 | 0.50 | 3.25 | 4.48 | 5.98 |
| 3 | 2.03 | 6.00 | 3.66 | 0.52 | 3.66 | 5.13 | 5.98 |

Figure 7

TEST IMPROVEMENT DIRECTIONS        Player no 2        Iteration no 3

INFO   CONF_COEF   NEW_REF   SELECT   GRAPH   SCROLL_CRIT   SCROLL_VAR   EXIT

Your confidence coefficient :    1.0000

| Var | Status quo | Reference point | Solution | Max conf coeff. | One shot solution | RA-utopia point | Ideal point |
|---|---|---|---|---|---|---|---|
| | MILK PRODUCTION | | | | [th liters] | | |
| 1 | 40.01 | 60.81 | 45.14 | 0.50 | 45.14 | 50.26 | 60.81 |
| 2 | 40.01 | 50.00 | 42.91 | 0.50 | 42.91 | 45.82 | 60.81 |
| 3 | 40.01 | 45.00 | 41.70 | 0.50 | 41.70 | 43.40 | 60.81 |
| | RYE PRODUCTION | | | | [th tonnes] | | |
| 1 | 2.66 | 3.76 | 2.93 | 0.50 | 2.93 | 3.20 | 3.76 |
| 2 | 2.66 | 4.00 | 3.05 | 0.50 | 3.05 | 3.44 | 3.76 |
| 3 | 2.66 | 4.00 | 3.12 | 0.50 | 3.12 | 3.57 | 3.76 |
| | SAVINGS OF TRACTOR POWER | | | [th tractor hours] | | | |
| 1 | 2.10 | 6.04 | 3.07 | 0.50 | 3.07 | 4.04 | 6.04 |
| 2 | 2.10 | 6.00 | 3.23 | 0.50 | 3.23 | 4.37 | 6.04 |
| 3 | 2.10 | 5.00 | 3.08 | 0.50 | 3.08 | 4.07 | 6.04 |

Figure 8

REPORT Player no 1 Iteration no 3

INFO SCROLL_CRITERIA EXIT

Joint confidence coefficient : 1.0000

MILK PRODUCTION [th liters]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 20.40 | 30.62 | 39.63 | 45.88 | 45.88 |


RYE PRODUCTION [th tonnes]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 0.60 | 0.98 | 1.32 | 1.53 | 1.53 |


SAVINGS OF TRACTOR POWER [th tractor hours]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 0.00 | 0.88 | 2.03 | 3.98 | 3.98 |


Figure 9

REPORT      Player no 2      Iteration no 3

INFO    SCROLL_CRITERIA    EXIT

Joint confidence coefficient :    1.0000

MILK PRODUCTION [th liters]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 31.00 | 35.19 | 40.01 | 41.70 | 41.70 |

1 2 3

RYE PRODUCTION [th tonnes]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 1.40 | 2.10 | 2.66 | 3.12 | 3.12 |

1 2 3

SAVINGS OF TRACTOR POWER [th tractor hours]

| Status quo | Agreement points in successive iterations 1 | 2 | 3 | One shot solution |
|---|---|---|---|---|
| 0.00 | 1.16 | 2.10 | 3.67 | 3.67 |

1 2 3

Figure 10