

MCBARG - Enhanced A System Supporting Multicriteria Bargaining

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Foreword

This paper is one of the new series of Working Papers presenting the software for interactive decision support and software tools for developing decision support systems. These products constitute the outcome of the contracted study agreement between the System and Decision Sciences Program at IIASA and several Polish scientific institutions. The contracted study agreement is a continuation of the previous scientific collaboration which is documented in the IIASA Working Paper WP-88-071 entitled *Theory, Software and Testing Examples in Decision Support Systems*.

This paper presents the MCBARG methodology and software, which is designed to support analysis of conflicting decision situations and mediations in multicriteria bargaining problem. The implemented approach utilizes the aspiration-led paradigm and concepts of interactive solutions in multicriteria bargaining. The enhanced version of the MCBARG presented here provides also an example which illustrates possibilities of application of MCBARG to a research being performed at IIASA. The software package described in this paper is available from the System and Decision Sciences Program.

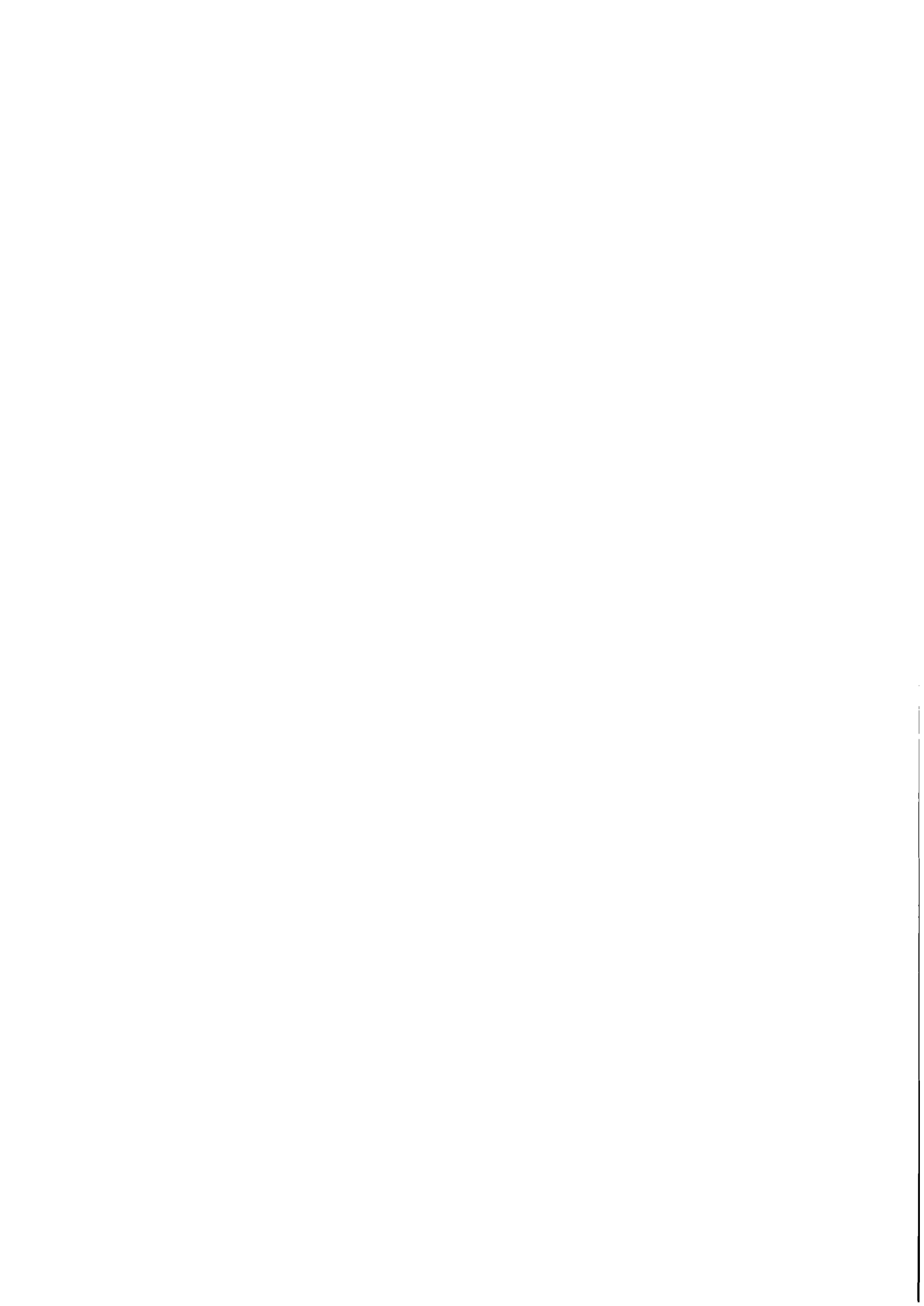
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Abstract

The MCBARG is a decision support system designed to help in the analysis of decision situations and in the mediation in multicriteria bargaining problems. It supports reaching the final outcome in the problem. The report describes an enhanced version of the MCBARG system. It provides the user with a theoretical foundation and with information necessary to use the system.

The system and the theoretical research have been done under a contracted study agreement with the Systems and Decision Sciences Program of the International Institute for Applied Systems Analysis in Laxenburg, Austria, and with financial support of the Research Program CPBP 02.15 of the Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland.



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1 Introduction

This paper deals with decision problems in multiactors game-like-situations in which the decision makers (individuals, firms, nations - "players") have conflicting interests and their final outcomes are determined within interactive bargaining. There are many complex situations in this class of problems in which the decision makers need help to learn about possible decision options and decision consequences. The MCBARG system enables learning process of the players, and supports reaching the final outcome in the multicriteria bargaining problem. It is based on some new theoretical results on interactive mediation processes with an application of aspiration-led methodology of decision support system.

The multicriteria bargaining problem is a generalization of classical bargaining problem, under the assumption that there are not given explicitly the utility functions of players. This generalization follows from the fact that an aggregation of players' objectives is often impossible because of various practical limitations of the utility theory. The problem is defined by an agreement set — the set of outcomes that can be reached under unanimous agreement of the players, and by a disagreement (status quo) point which is a result of the problem if there is no such an agreement.

The interactive mediation process is described by a procedure which consists in generation of a sequence of outcomes leading to a nondominated solution. The procedure is based on a limited confidence principle, taken from practical observation, which says that the players have limited confidence in their ability to predict consequences and possible outcomes, hence each player tries to prevent other players from receiving disproportionately large gains. The generated outcomes are consistent with preferences of the players. The procedure assures some fairness rules and is resistant to the various manipulations of the players.

The MCBARG system includes a generator and an editor of the model of the bargaining problem for which the interactive procedure is performed. The model describes the agreement set in form of a set of inequalities, and the status quo point. The generator and the editor enable introducing linear or nonlinear formulae defining the inequalities using standard arithmetic operators and some common functions.

This latest version of the MCBARG system includes the following extensions in comparison to the older version described by Bronisz P., L. Krus, B. Lopuch (1988):

— A new user interface of the system has been elaborated including a new system of menus, new options, and new graphical presentation of results, which makes, as it seems, the system more user-friendly.

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— In this version, explicit division of roles of the system analyst (named in the system "OPERATOR") and of the players has been introduced. It is assumed, that at first the bargaining problem is prepared by the system analyst, next, the system analyst begins and conducts the negotiation procedure in which human players participate.

— The players have limited access to the counterplayers information. The information is protected by passwords.

— The players can simulate and analyze the counterplayers decisions and their impact on the obtained outcomes. In the older version, the counterplayers decisions during the unilateral analysis were assumed by default values of the system.

— A new option **OLD SESSION** has been introduced. The system enables a user to save a performed session on a disk. The saved session can be analyzed, and if needed, can be used to restart the negotiation procedure.

— The editor of the model and the solver procedures have been modified. In the model of the bargaining problem minimized and maximized criteria can be explicitly formulated. In the older version all criteria were assumed to be maximized. New routines for checking formal correctness of the model and proper formulation of the bargaining problem have been included.

— A new illustrative example referring to an international cooperation on the acid rains problem has been elaborated and used as a tutorial in the paper.

This report is organized as follows. Section 2 contains mathematical formulation of the multicriteria bargaining problem and methodological background of solution concept and of interactive algorithm. Section 3 explains the use of the system, i.e. how to create model of a bargaining game and how to support mediation. Section 4 presents an illustrative example of a bargaining game played with the system support. Section 5 contains technical information.

Section 2 is a revised version of the theoretical foundations presented in the description of the previous version of the MCBARG system. Sections 3, 4 and 5 have been completely rewritten to cover the new version of the MCBARG system.

2 Theoretical foundations

2.1 Introduction

In most approaches (see Nash, 1950, Raiffa, 1953, Kalai and Smorodinsky, 1975, Roth, 1979), the bargaining problem has been considered in the case of unicriterial payoffs of players, i.e. when the preferences of particular players are expressed by utility functions. In many practical applications however, players trying to balance a number of objectives might have difficulties while constructing such utility functions. Moreover, the classic literature considers mostly axiomatic models of bargaining which yield one-shot solutions and do not result in procedures describing a process of reaching a binding agreement.

We consider n players, each with several objectives, so we deal with a multiobjective bargaining problem. In this problem, the players are faced with an agreement set of feasible outcomes. Any such outcome can be accepted as the result if it is specified by an unanimous agreement of all players. In the event that no unanimous agreement is reached, the status quo point is the result. If there are feasible outcomes which all participants prefer to the status quo point, then there is an incentive to reach an agreement. In most situations, players differ in their opinions about which outcome is most preferable, hence there is a need for bargaining and negotiation.

When dealing with multiple payoffs, we do not assume that there exist explicitly given utility functions of the players. In this case the solution can be found in an interactive procedure. Such a procedure is considered here. The procedure starts from the status quo point and leads to a nondominated, individually rational solution belonging to the agreement set. During the interaction, players can express their preferences and can influence the course of the iterative process.

2.2 Problem formulation and definitions

Let $N = \{1, 2, \dots, n\}$ be the finite set of players, each player having m_i objectives. A multiobjective bargaining problem is defined as a pair (S, d) , where an agreement set S is a subset of $\sum_{i=1}^n m_i$ - dimensional Euclidean space, called R^{NM} , and a disagreement point (status quo point) d belongs to S .

The bargaining problem has the following interpretation: every point $x \in R^{NM}$, $x = (x_1, x_2, \dots, x_n)$, $x_i = (x_{i1}, x_{i2}, \dots, x_{im_i})$, in the agreement set S represents payoffs for all the players that can be reached when they do cooperate with each other (x_{ij} denotes the payoff of the j -th objective for the i -th player). If the players do not cooperate, the disagreement point is the result.

Each objective can be maximized or minimized. For simplicity of problem formulation in Section 2 we assume that all objectives are maximized.

We employ a convention that for $x, y \in R^k$, $x \geq y$ implies $x_i \geq y_i$ for $i = 1, \dots, k$, $x > y$ implies $x \geq y$, $x \neq y$, $x \gg y$ implies $x_i > y_i$ for $i = 1, \dots, k$. We say that $x \in R^k$ is a weak Pareto optimal point in X if $x \in X$ and there is no $y \in X$ such that $y \gg x$; $x \in X$ is a strict Pareto optimal point in X if there is no $y \in X$ such that $y > x$.

We confine our consideration to the class of all multicriteria bargaining games (S, d) satisfying the following conditions:

- (i) S is compact and there is $x \in S$ such that $x > d$,
- (ii) S is comprehensive, i.e. for $x \in S$ if $d \leq y \leq x$ then $y \in S$.
- (iii) For any $x \in S$, let $Q(S, x) = \{i : y \geq x, y_i > x_i \text{ for some } y \in S\}$. Then for any $x \in S$, there exists $y \in S$ such that $y \geq x$, $y_i > x_i$ for each $i \in Q(S, x)$.

Condition (i) states that the set S is closed, upper bounded and the problem is not degenerated. Condition (ii) says that objectives are disposable, i.e. that if the players can reach the outcome x then they can reach any outcome worse than x . $Q(S, x)$ is the set of all coordinates in R^{NM} , payoffs of whose members can be increased from x in S . Condition (iii) states that the set of Pareto optimal points in S contains no "holes". We do not assume convexity of S , however, any convex set satisfies Condition (iii).

The problem consists in supporting the players in reaching a nondominated solution, agreeable and close to their preferences.

Definitions:

A point $x^i \in S$ is defined as i -nondominated, $i \in N$, if there is no $y \in S$ such that $y_i > x^i_i$. A point $u \in R^{NM}$ is defined as a *utopia point relative to aspirations* (RA utopia point) if for each player $i \in N$, there is an i -nondominated point $x^i \in S$ such that $u_i = x^i_i$.

The i -nondominated point is an outcome which could be achieved by a rational player i if he would have full control of the moves of the other players. Let us observe that if in the unicriterial set there is only one i -nondominated point, then in the multicriteria case considered here there is a set of such points. Each player i , $i \in N$, is required then to investigate the set of i -nondominated points in S as m_i -dimensional multicriteria decision problem and then to select one i -nondominated point as his most preferable outcome.

The RA utopia point generated by the selected i -nondominated points, $i \in N$, carries information about the most preferable outcomes for all the players. The RA utopia point significantly differs from the ideal (utopia) point defined by the maximal values of all objectives in set S .

2.3 Interactive procedure

We are interested in a constructive procedure that is acceptable to all the players, starts at the status quo point and leads to a strict Pareto optimal point in S . The procedure can be described as a sequence, $\{d^t\}_{t=0}^k$, of agreement points d^t such that $d^0 = d$, $d^t \in S$, $d^t \geq d^{t-1}$, for $t = 1, 2, \dots$, d^k is a strict Pareto optimal point in S . (The assumption $d^t \geq d^{t-1}$ follows from the fact that no player will accept improvement of payoffs for other players at the cost of his concession.) At every round t , each player $i \in N$ specifies his preferable reference point $r_i^t \in R^{m_i}$, $r_i^t > d_i^t$ defining his improvement direction $\lambda_i^t \in R^{m_i}$, $\lambda_i^t = r_i^t - d_i^t$, and proposes his confidence coefficient $\alpha_i^t \in R$, $0 < \alpha_i^t \leq 1$. The improvement direction λ_i^t indicates the i -th players preferences over his objectives at round t . The confidence coefficient α_i^t reflects his ability at round t to describe preferences and to predict precisely all consequences and possible outcomes in S . (For more detailed justification, see Fandel, Wierzbicki, 1985, and Bronisz, Krus, Wierzbicki, 1988).

We propose an interactive negotiation process defined by a procedure:

$$(*) \quad \begin{aligned} & \{d^t\}_{t=0}^\infty \quad \text{such that} \quad d^0 = d, \\ & d^t = d^{t-1} + \varepsilon^t * [u(S, d^{t-1}, \lambda^t) - d^{t-1}] \quad \text{for } t = 1, 2, \dots, \end{aligned}$$

where

$\lambda^t \in R^{NM}$, $\lambda^t = (\lambda_1^t, \lambda_2^t, \dots, \lambda_n^t)$, is the improvement direction specified jointly by all the players,

$u(S, d^{t-1}, \lambda^t) \in R^{NM}$ is the utopia point relative to the direction λ^t at round t defined by

$$u(S, d^{t-1}, \lambda^t) = (u_1(S, d^{t-1}, \lambda_1^t), u_2(S, d^{t-1}, \lambda_2^t), \dots, u_n(S, d^{t-1}, \lambda_n^t)),$$

$$u_i(S, d^{t-1}, \lambda_i^t) = \max_{\geq} \left\{ x_i \in R^{m_i} : x \in S, x \geq d^{t-1}, x_i = d_i^{t-1} + a\lambda_i^t \text{ for some } a \in R \right\},$$

$$\varepsilon^t = \min(\alpha_1^t, \alpha_2^t, \dots, \alpha_n^t, \alpha_{\max}^t) \in R, \text{ where } \alpha_{\max}^t \text{ is the maximal number } \alpha \text{ such that } d^{t-1} + \alpha[u(S, d^{t-1}, \lambda^t) - d^{t-1}] \text{ belongs to } S.$$

The utopia point $u(S, d^{t-1}, \lambda^t)$ relative to the aspirations of the players (relative to direction λ^t) reflects the preferences of the particular players when the improvement direction λ^t is specified at round t . The individual outcome $u_i(S, d^{t-1}, \lambda_i^t)$ is the maximal payoff in S for the i -th player from d^{t-1} according to the improvement direction λ_i^t , while ε^t is the minimal confidence coefficient of the players at round t (we assume that no player can agree on a coefficient greater than his) such that a new calculated agreement point belongs to S . The preferable direction λ_i^t at round t is specified on the basis of interactive scanning of a number of solutions generated for assumed by players different reference points. The proposed approach is very close to the achievement function concept (Wierzbicki, 1982) from the point of view of the user. Analogously, a special way of the parametric scalarization of the multiobjective problem is utilized to be an influence on

the selection of solutions by changing reference points. To solve the problem, directional maximization is applied, using a bisection method. (see Bronisz and Krus, 1988). The scanning (called in the system the improvement directions testing) is performed independently by each of players. Given the information about the current status quo and ideal point the player proposes a number of reference points and confidence coefficient. For each reference point $r_i^t > d_i^t$ and confidence coefficient α_i^t given by the player at the round t , the system calculates:

RA-utopia:

$$u_i(S, d^{t-1}, \lambda_i^t) = \max_{\geq} \left\{ x_i \in R^{m_i} : x \in S, x \geq d^{t-1}, x_i = d_i^{t-1} + a\lambda_i^t \text{ for some } a \in R \right\},$$

one-shot solution:

$$x^t = \max_{\geq} \left\{ x \in S : x = d^{t-1} + a * [u(S, d^{t-1}, \lambda^t) - d^{t-1}] \text{ for some } a \in R \right\},$$

anticipated solution:

$$y^t = d^{t-1} + \varepsilon^t * [u(S, d^{t-1}, \lambda^t) - d^{t-1}]$$

maximal confidence coefficient:

$$\alpha_{\max}^t = \max_{\geq} \left\{ a \in R : d^{t-1} + a * [u(S, d^{t-1}, \lambda^t) - d^{t-1}] \in S \text{ for some } a \in R \right\},$$

where $\lambda^t \in R^{NM}$, $\lambda^t = (\lambda_1^t, \lambda_2^t, \dots, \lambda_n^t)$, $\lambda_j^t = \lambda_j^{t-1}$ for $j \neq i$, $\lambda_i^t = r_i^t - d_i^t$, $u(S, d^{t-1}, \lambda^t) \in R^{NM}$ is the utopia point relative to the direction λ^t .

Having the above information for a number of reference points, the player then selects his preferred one. It defines the improvement direction of this player. Defined in this way, improvement directions of all the players λ_i^t are used for the calculation of the result d^t of the negotiation round.

The procedure is based on the following theoretical result (see: Bronisz, Krus, Lopuch, 1987, and Bronisz, Krus, Wierzbicki, 1988):

Theorem 1. For any multicriteria bargaining game (S, d) satisfying conditions (i), (ii) and (iii) and for any confidence coefficients α_i^t such that

$$0 < \varepsilon \leq \alpha_i^t \leq 1, \quad t = 1, 2, \dots, T$$

there is a unique process d^t , $t = 0, 1, \dots, T$, $T \leq \infty$, described by (*) satisfying the following postulates:

- P1. $d^0 = d$, $d^t \in S$ for $t = 1, 2, \dots, T$,
- P2. $d^t \geq d^{t-1}$ for $t = 1, 2, \dots, T$,
- P3. d^T ($= \lim_{t \rightarrow \infty} d^t$ if $T = \infty$) is a strict Pareto optimal point in S .
- P4. *Principle of α -limited confidence.* Let $0 < \alpha_i^t \leq 1$ be a given confidence coefficient of the i -th player at round t . Then acceptable demands are limited by:

$$d^t - d^{t-1} \leq \alpha_{\min}^t [u(d^{t-1}) - d^{t-1}] \text{ for } t = 1, \dots, T,$$

where α_{\min}^t is a joint confidence coefficient at round t , $\alpha_{\min}^t = \min \{\alpha_1^t, \dots, \alpha_n^t\}$, $u(d^{t-1})$ is the RA-utopia point which reflects the preferences of the players in the subset of the set S given by $\{x \in S : x \geq d^{t-1}\}$

P5. *Principle of recursive rationality.* Given d^t , at each round t , there is no such outcome $x \in S$, $x > d^t$, that x satisfies P4 (x substitutes d^t in P4).

P6. *Principle of proportional gains.* For each round t , $t = 1, \dots, T$, there is a number $\beta > 0$ such that

$$d^t - d^{t-1} = \beta[u(d^{t-1}) - d^{t-1}].$$

The presented approach has been examined in a case of one-round process with confidence coefficients of the players equal to one. The corresponding one-shot solution has been characterized axiomatically (Bronisz and Krus, 1987a). It is easy to notice that in the unicriterial case, each game (S, d) has a unique utopia point which coincides with the ideal point and the one-shot solution coincides with the Raiffa solution (see Raiffa, 1953, Roth, 1979).

It is assumed that after testing of right amount of reference points each player selects his preferable direction. However, it may happen that a player has not sufficiently tested his set of nondominated points and selects a weak Pareto outcome as his preferable result. In such a case, even if all the players assume the confidence coefficients greater than the values of maximal confidence coefficients, the procedure should proceed in several iterations more, until it reaches a strict Pareto solution in S . In the system this inconvenience is removed by the application of an option of lexicographical improvement of a weak Pareto solution to a strict Pareto one without interaction of the players. The option is used only in the case that all the players assume their confidence coefficients greater than the values of maximal confidence coefficients. In such a case it is assumed that they are going to finish the interactive process. The lexicographical improvement proceeds in the following way:

Let us assume that in round t the obtained agreement point

$$d^t = d^{t-1} + \varepsilon * [u(S, d^{t-1}, \lambda^t) - d^{t-1}]$$

is a weak Pareto optimal. For a finite subsets of integer numbers I, J , let

$$e(I, J) = (e_1(I, J), \dots, e_n(I, J)) \in R^{NM}$$

be such that $e_{ij}(I, J) = \lambda^t$ for $i \in I$ and $j \in J$, otherwise $e_{ij}(I, J) = 0$.

Given $y \in S$ with $Q(S, y) \neq \emptyset$, define $x(S, y) \in S$ by

$$x(S, y) = \max_{\geq} \{ x \in S : x = y + a * e(Q(S, y)) \text{ for some } a \in R \}.$$

Intuitively, the vector $e(Q(S, y))$ includes all the coordinates of vector λ^t , and along with the solution may be improved. Otherwise, the corresponding coordinate of the vector $e(Q(S, y))$ is equal to 0. Then the lexicographical improvement can be defined by the sequence $\{x^j\}_{j=0}^{\infty}$ such that $x^0 = d^t$, and $x^j = x(S, x^{j-1})$ for $j = 1, 2, \dots$. It is shown (Bronisz and Krus, 1988) that there is exactly one such sequence, moreover this sequence is finite.

The presented lexicographical improvement has been examined in a case of one-round process, i.e. when a weak Pareto optimal solution is reached in the first round. It is shown (Bronisz and Krus, 1988) that in such a case the solution of the bargaining process can be described with the Rawlsian lexmin principle (Rawls, 1971). Moreover, in the unicriterial case, the solution coincides with the Imai solution (Imai, 1983).

3 User guide

3.1 General information

The MCBARG system is a decision support system designed to help in analysis of a decision situation and mediation in multicriteria bargaining problem in which a mathematical model of the problem can be formulated by a status-quo point and a system of inequalities describing agreement set in objective space of the players.

The program is recorded on one diskette that can be installed on an IBM-PC-XT, AT or compatible computer with Hercules Graphics Card, Color Graphic Adapter (CGA) or Enhanced Graphics Adapter (EGA). A diskette contains compiled code of the program together with some data files for a demonstrative example of the bargaining problem.

The system supports the following general functions:

1. The definition and edition of a model of the bargaining problem.
2. The analysis of the bargaining problem and performing interactive negotiation-mediation procedure.

The model definition and edition should be done by a system analyst called further in the system an OPERATOR. The OPERATOR prepares and conducts the interactive negotiation procedure. He gives a control to players during performing negotiation-mediation session. He takes control over the system again after the session is interrupted or finished.

The interactive procedure is performed by human players. It proceeds in a number of iterations (rounds) and in each iteration the system supports the players in:

- Initial multiobjective analysis of the bargaining problem resulting in an estimation of bounds on efficient outcomes and learning about the extreme and neutral outcomes.
- Unilateral, interactive analysis of the problem with stress on learning, organized through system response to user specified confidence coefficients and aspiration levels for objective outcomes.
- Calculation of the multilateral, cooperative solutions according to player preferences.

The system is operated with the use of a set of menus. Particular options can be selected by the option first letter or by cursor and <Enter> key.

The system is self-explaining, it includes a set of information facilitating working with the system.

All of the screens include a highlighted head bar which displays the current phase of the system where the user is, and a bottom help bar displaying operating keys.

In the following subsections more detailed information about particular options of the system menus is presented.

3.2 Main Menu

INFORMATION option

The INFORMATION option presents general information about the system.

MODEL option

The **MODEL** option enables definition and edition of a model of bargaining problem. The bargaining problem is described by a set of players having several criteria, by an agreement set and by a status quo point.

The following options of **MODEL** menu allow:

- INFORMATION** – present the information about the actual phase of work,
- LOAD** – load an existing model or give a name to a new one,
- EDIT** – edit an existing model or create a new one,
- BUILD** – translate the loaded model into an internal form and perform initial calculations,
- QUIT** – exit to **MAIN** menu.

The **LOAD** option enables the selection of a model from displayed model names or the insertion of a new model name (each model is stored in a file having the model name and the default extension **.MOD**). Short information about the highlighted model including its name, number of players, their names and numbers of criteria is given in the window on the right side of the screen.

The **EDIT** option enables edition or creation of a model. The built-in editor is especially designed for this purpose. This option invokes the **EDIT MODEL** menu described in the following section.

To utilize the model in the **NEGOTIATION** option of the **MAIN** menu first it has to be translated into an internal form. This is done by the **BUILD** option. The system performs the needed initial calculations and checks the correctness of the model of bargaining problem. In particular, it is checked whether the agreement set is bounded, and the status quo point belongs to the agreement set.

OLD SESSION option

The option makes it possible load and view an old session. It is useful for analysis as well as for restarting from the previously performed and saved session. Options displayed at **OLD SESSION** menu enable to:

- INFORMATION** – present the information about the actual phase of work,
- LOAD** – load an old session,
- VIEW** – view the session results,
- PRINT** – print the session report,
- QUIT** – exit to **MAIN** menu.

The **LOAD** option enables the selection of a session from displayed session names (each session is stored in a file having the session name and the default extension **.SES**). Short information about the highlighted session including: model and session name, number of

players, their names and numbers of criteria, is given in the window on the right side of the screen.

The **VIEW** option supports reviewing the results obtained in succeeding iterations of the session selected with the use of the **LOAD** option. The following information are presented on the screen:

- player name,
- number of reviewed iteration,
- status of the session (finished or not),
- confidence coefficients: joint and assumed by the player

next in the upper table:

- status quo,
- agreement outcomes in the previous iteration,
- agreement outcomes in the given iteration,
- one-shot solution,
- ideal point

and in the lower table

- graphical presentation of results. The bars represent improvements obtained at the agreement solution in comparison to the status quo (scaled by the distance between the status quo and the ideal point), starting from the left side of the window for the criteria to be maximized, and from the right side - for the minimized ones. The highlighted part of the bar represents the improvement obtained in comparison to the previous iteration result.

The **OPERATOR** can use following set of keys:

- <left, right arrow> - scroll the reviewed iterations,
- <Ctrl PgUp, Ctrl PgDn> - set active criterion (to be scrolling),
- <PgUp, PgDn> - scroll the criteria,
- <Ctrl P> - scroll the players.

The **PRINT** option makes it possible to print a report of the current session in aggregated or in detailed form. In the aggregated report only the status quo, the ideal point and the agreement points at succeeding iterations are presented. In the detailed report all the data presented at **VIEW** option are printed.

NEGOTIATION option

The **NEGOTIATION** option activates the negotiation-mediation procedure. This version of the system is built for one computer, therefore the players can enter into the system in a sequence, once at each iteration. In the case where one of the players interrupts the procedure or the session is finished, the control should be given to the **OPERATOR**.

The information devoted to a particular player is protected with the use of a password. The password is fixed during the first entry of the player or the **OPERATOR**. Before the session, the players should agree upon a level of availability of their information to the counterplayers. There are three possibilities in the system, called access levels:

- LEVEL 0 – no access to information about counterplayers criteria nor results,
- LEVEL 1 – access to information about counterplayers criteria and past results, possible simulation of the counterplayers decisions and observation of their effect on the player results,
- LEVEL 2 – access to information about counterplayers criteria and past results, possible simulation of the counterplayers decisions, and observation of their effect on the player and the counterplayers results.

The agreed player access level, to be enforced in the session, is entered by the OPERATOR at the beginning of the session.

Any player or OPERATOR enters the system by selection of his name. The player takes control over the system with use of the NEGOTIATION menu, while the OPERATOR with use of the OPERATOR menu.

3.3 Edit Model Menu

To create a new model the following values must be entered with use of the EDIT MODEL menu :

- number of players and their names (PLAYERS option).
Minimum: 2 players. Maximum: 5 players.
- number of criteria of each player (CRITERIA option).
Minimum: 1 criterion. Maximum: 8 criteria.
- description of criteria (<F2> key in CRITERIA option).
- criteria units (<F3> key in CRITERIA option).
- status of the criteria - min for minimized and max for maximized (<F4> key in CRITERIA option).
- status quo value for each criterion (<F3> key in CRITERIA option).
Default: 0.0.
- set of formulae describing the agreement set (FORMULAE option).

The players are recognized by their names. To facilitate a description of criteria names in formulae, the criterion of the given player has the following alphanumeric code: "1n", where 1 means letter of the given player (a or A — first player, b or B — second player, and so on), n denotes number of the criterion. (For example, "c2" means variable for the second criterion of the third player).

The set of formulae describing an agreement set should be in the form:

```

formula_name_1 = expression_1 ;
formula_name_2 = expression_2 ;
.....
formula_name_N = expression_N ;

```

which gives the following set of inequalities:

$$\text{expression}_I \geq 0 \quad \text{for } I = 1, 2, \dots, N.$$

A `formula_name_I`, $I = 1, \dots, N$, should begin with a letter. It can be treated as a comment to an `expression_I`. An `expression_I`, $I = 1, \dots, N$, is Pascal-language-like expression, which can include:

- constants — in normal or in exponential form;
- variables for criteria — as presented in the above alphanumeric code “ln”;
- operators divided into 4 categories, listed by their order of precedence:

- 1) Exponentiation: \wedge ,
- 2) Unary minus: $-$,
- 3) Multiplying operators: $*$, $/$,
- 4) Adding operators: $+$, $-$;

- parentheses: $(,)$;
- arithmetic functions: `sin`, `cos`, `exp`, `log`.

`sin` – returns the sine of the argument (the argument is expressed in radians),
`cos` – returns the cosine of the argument (the argument is expressed in radians),
`exp` – returns the exponential of the argument,
`log` – returns the natural logarithm of the argument.

The argument of each function should be written in parentheses.

EXAMPLE of a formula for two players, each one having two criteria:

```
formula = 1000 - a1 - exp(a2+b1) - ( b2 - 1.05e-2 )^2 ;
```

An edited model is stored in the memory, if you want to use the same model in the future you should write it on the disk when leaving the `EDIT MODEL` option.

The `BUILD` option performs the same actions as the `BUILD` option in the `MODEL` menu (translates the model into an internal form and performs needed initial calculations). It is included into this menu for user convenience.

3.4 Negotiation Menu

Each player enters the system by selection of his name and typing the password. The following options of `NEGOTIATION` menu allow him to:

`INFORMATION` – present the information about the actual phase of work,

`DECISION` – test and make decision in the given iteration,

`VIEW` – view obtained results,

`PRINT` – print the current session report,

`QUIT` – exit to the `NEGOTIATION` option.

DECISION option

The DECISION option enables testing different improvement directions starting from the last agreement point (in the first iteration it is a status quo point). It allows for an interactive scanning of variants of outcomes. The variants are generated by the player for specified reference points. The points correspond to the improvement directions. The resulting outcomes are calculated for the player at the assumed confidence coefficient and at the assumed improvement directions of the other players. By the scanning the player can test his preferences and select his preferable outcome and corresponding reference point.

The following options of the DECISION menu allow the player:

- CONF_COEF – specification of confidence coefficient,
- NEW_REF – specification of reference point and creation of a new variant,
- VIEW_CNTR_PL – displaying results for simulated counterplayers actions (accessible for the LEVEL 1 and the LEVEL 2 only),
- SELECT – selection of the preferable variant,
- QUIT – exit to the DECISION menu.

The keys presented in bottom help lines enable:

- scrolling the variants (<Tab> and <Up, Dn arrows>),
- scrolling the criteria (<Ctrl PgUp>, <Ctrl PgDn>, <PgUp>, <PgDn>),
- displaying the anticipated solution in the graphical form (<Ctrl G>).

Using these options the player can create and compare a number of outcome variants. The system presents:

- status quo,
- cooperative solution obtained at the previous iteration (Prev. sol.),
- ideal point.

These values define a range of possible outcomes and reasonable reference points.

The created variants are stored on the disk. The first variant is created by the system, under the assumption that the improvement direction is defined according to the ideal point, and serves the player introductory information. The solution presented at this variant is called the neutral solution.

For each variant the system calculates and presents:

- anticipated outcomes (Ant. sol.),
- utopia points relative to aspirations of the player (RA-utopia point).

The RA-utopia point denotes the outcomes the player could obtain under the assumption that the other players get no improvement at this iteration. The anticipated outcomes are calculated for the assumed actions of the counterplayers. By system default, these actions are based on the variants selected by the counterplayers at the previous iteration (in the 1-st iteration the ideal point is taken).

The **CONF_COEF** and **NEW_REF** options can be used for generation of a new variant. The **CONF_COEF** option makes it possible to specify to the player the assumed value of this iteration confidence coefficient (within the range (0, 1]). The **NEW_REF** option enables one to enter the references for the player's objectives for which the outcome will be calculated. In the case of **LEVEL 0** the values for the counterplayers references are specified by the system. In the case of **LEVEL 1** and **LEVEL 2**, the player can accept the default values for the counterplayer references or specify them himself.

Comparison of outcomes from different assumed actions of counterplayers is possible with use of the **VIEW_CNTR_PL** option. This option can be activated only for the access **LEVEL 1** and **LEVEL 2**. Selecting this option the player obtains information on his one-shot outcomes (in the case of **LEVEL 1** access) and on one-shot outcomes of counterplayers (in case of the **LEVEL 2** access). The one-shot solution denotes outcomes the player could obtain under the assumption of the full confidence (i.e. confidence coefficient equal to one). The information is presented in two tables - the table on the left side of the screen relates to the particular counterplayer, the table on the right side - to the active player. Scrolling the counterplayers can be done with use of <Ctrl P> keys, toggling the left and right tables with use of <left and right arrow> keys, scrolling variants and criteria - as mentioned above.

After making some tests for different improvement directions, the player should specify the preferable variant. The **SELECT** option is used for this purpose. This variant will be the base for the agreement point calculation. The agreement solution at the given iteration is calculated when all the players have made their decisions. Then the system starts the next iteration.

VIEW option

The **VIEW** option supports reviewing the results obtained in the previous iterations. The following information is presented on the screen:

- player or the counterplayer name to which the information refers,
- number of reviewed iterations,
- status of the session (finished or not),
- confidence coefficients: joint and assumed by the operating player,

below of this in the upper table:

- status quo,
- agreement outcomes in the previous iteration,
- agreement outcomes in the given iteration,
- one-shot solution,
- ideal point

and in the lower table

- graphical presentation of results.

The bars represent improvements obtained at the agreement solution in comparison to the status quo (scaled by the distance between the status quo and the ideal point), starting from the left side of the window for the criteria to be maximized, and from the right side - for the minimized ones. The highlighted part of the bar represent the improvement obtained in comparison to the previous iteration result.

The player can use the following set of keys:

- <left, right arrow> - scroll the reviewed iterations,
- <Ctrl PgUp, Ctrl PgDn> - set active criterion (to be scrolling),
- <PgUp, PgDn> - scroll the criteria,
- <Ctrl C> - view the counterplayers (<Ctrl P> - scroll the counterplayers, <Ctrl Y> - return to the operating player).

The information about the counterplayers is presented only if the access LEVEL 1 or LEVEL 2 has been chosen.

PRINT option

The PRINT option makes it possible to print a report of the current session in aggregated or in detailed form. In the aggregated report only the status quo point, the ideal point and the agreement points at succeeding iterations are presented. In the detailed report all the data presented at VIEW option are printed. Results of the counterplayers are printed in the case of the LEVEL 1 and LEVEL 2 accesses.

QUIT option

Warning!

The player should not leave the NEGOTIATION menu before making a decision defining the preferable improvement direction. It is done by selecting the preferable variant with the use of the SELECT option of the DECISION menu. Otherwise, the system assumes that the player interrupts the session.

3.5 Operator Menu

The OPERATOR can take control over the system during the negotiation procedure at each iteration. He should take the control if the session has been interrupted or finished. The OPERATOR menu includes the following options which allows him to:

- VIEW - view the players results,
- PRINT - print the session report,
- CONTINUE - continue the session,
- QUIT - exit to MAIN menu.

The description of the VIEW and PRINT options is analogical as in the case of OLD SESSION menu. The OPERATOR has full access to the information, disregarding the access level enforced in this session.

The CONTINUE option allows the players to continue the negotiation-mediation procedure.

At the QUIT option the OPERATOR can save the performed session.

4 Example session

After starting from the distributed disk using command line: MCBARG, the system will be loaded and you will see on the first screen full name of the program, names of the authors and institutions, version number and date of release (Figure 1).

```

                                MCBARG - Enhanced
SYSTEM SUPPORTING MULTICRITERIA BARGAINING
  by  L. Krus,   P. Bronisz,   B. Lopuch
      Enhanced version   September 1990
      in Systems Research Institute,
      Polish Academy of Sciences, Warsaw, Poland
      for System and Decision Sciences Program,
      International Institute for Applied Systems Analysis,
      Laxenburg, Austria (Copyright)

```

Press any key ...

Figure 1

In this example session it is assumed that you play the role of an OPERATOR (the system analyst who prepares and conducts the session) and the roles of players participating in the mediation procedure.

You start the work as the OPERATOR. Just press any key. The program will ask you to enter the OPERATOR password. If you do not use the password just press the <Enter> key. After that the first menu will be displayed (Figure 2). It is the MAIN menu and appears in the left upper corner of the screen.

On the top of the screen you can see the highlighted bar (head bar). In the bar, OPERATOR or Player names are displayed depending on who has access to the system at the current phase.

At the bottom of the screen you can see another highlighted bar (help bar) with a brief explanation of all active keys at the moment. The help bars will appear during all phases of the work with the system.

Notice that one of the commands (options) of menu is highlighted. This is the command where the cursor is resting. You can activate this command by pressing the <Enter> key or you can move to another command using the arrow keys. You can also activate the requested command by pressing its first letter key. There is, however, one thing you should remember: you can not use the commands in any order. First you have to establish the active model (the MODEL or OLD SESSION option) and then you can start playing with it. If it is not obvious what to do next, just press <F1> key (HELP) or select the INFORMATION option for more information.

```

      MAIN MENU
    INFORMATION
      MODEL
    OLD SESSION
    NEGOTIATION
      QUIT
  
```

```

↑ ↓ Home End -move bar ← -select option F1 -help ESC -abort.
  
```

Figure 2

Let us continue our session. If the cursor remains on the MODEL option, just press the <Enter> key. The system will transfer control to the MODEL menu displayed in Figure 3.

Once again, you are asked to select an option from the above menu. At first, select the LOAD option. (Other options will be inactive). Your screen will look like Figure 4.

In the bottom window you will see names of the models created during the previous sessions. Choose the model named ACID.

The ACID model relates to the problem of cooperation of two countries trying to decrease deposition of acid rains (in particular of sulfur). This will be our illustrative example to show how you can work within the MCBARG system. The story describing a bargaining problem is as follows:

There are two countries disputing programs reducing sulfur emissions. Each country is assumed to have an adopted plan for emission control and expects the emission level \underline{E}_i . However it is also assumed that the deposition levels resulting from the $\underline{E}_i, i = 1, 2$ are regarded as unacceptable, therefore an additional emission control program is requested and required for the program expenditures are discussed.

For each country $i = 1, 2$ there is a given cost function describing minimal required total cost C_i of reducing the total emission from the level \underline{E}_i to the level E_i . The function is assumed to be decreasing and piece-wise linear.

The sulfur depositions in country i is described by the equation:

$$D_i = a_{i1}E_1 + a_{i2}E_2 + \underline{D}_i, i = 1, 2$$

where $a_{i,j} (i, j = 1, 2)$ are parameters of the atmospheric transportation matrix (so called European Monitoring and Evaluation Programme matrix), \underline{D}_i are depositions from emission of the other countries.

(The model was inspired by the paper by Bergman L., H. Cesar, G. Klaassen (1990), however in our paper a different approach based on the interactive bargaining is proposed).

The following two situations can be considered.

OPERATOR

```
MODEL MENU
INFORMATION
LOAD
EDIT
BUILD
QUIT
```

↑ ↓ Home End -move bar ← -select option F1 -help ESC -abort.

Figure 3

```
OPERATOR MODEL: AGRICO

MODEL MENU
INFORMATION
LOAD
EDIT
BUILD
QUIT

Model : AGRICO
No. of Players: 2
play1      No. of Criteria: 3
play2      No. of Criteria: 3

LOAD
AGRICO ACID

Select file with ↑↓↔→ Home or enter name:

ESC -abort
```

Figure 4

The first case deals with unilateral actions of the countries. In this case each country is assumed to enforce independently his additional program reducing sulfur emission. Paying $\bar{X}_i = \bar{C}_i$, it achieves the emission \bar{E}_i and deposition \bar{D}_i calculated with use of the cost function and the deposition equation (where \bar{C}_i is cost of the program).

In the second case cooperation of the countries is assumed, in a form of a bilateral agreement on a joint reducing program. In this case a joint fund is created, and the following equation is added to the model description:

$$X_1 + X_2 = C_1 + C_2$$

where X_i , $i = 1, 2$ are shares of the countries in the joint fund, C_i , $i = 1, 2$ are costs of reducing the emissions in particular countries. In this case a multicriteria optimization problem can be considered in which the expenditures X_1 , X_2 and the depositions D_1 , D_2 are minimized subject to the constraints described by the cost functions, the deposition equations and the equation defining the joint fund with respect to the variables: the costs C_1 , C_2 and the emissions E_1 , E_2 . Solutions of the problem lay on a Pareto boundary of a simplex S in the four-dimensional objective space. Let S_+ be defined by

$$S_+ = \{(X_1, X_2, D_1, D_2) : (X_1, X_2, D_1, D_2) \leq (\bar{X}_1, \bar{X}_2, \bar{D}_1, \bar{D}_2), (X_1, X_2, D_1, D_2) \in S\}$$

and called an agreement set. If S_+ is not empty, it describes benefits the countries can achieve as an effect of cooperation in comparison to the first case. This is an incentive to cooperation.

The bargaining problem consists of looking for an efficient solution in an agreement set, being subset of the simplex S , of all points dominating the point $d = (\bar{X}_1, \bar{X}_2, \bar{D}_1, \bar{D}_2)$, called further a status quo or a disagreement point. The solution should be selected according to the preferences of the countries considered further as players, and should assure the "fairness" rule. Roughly speaking, the problem consists in proper, agreeable to both the countries allocation of the benefits resulting from the cooperation. The MCBARG system supports analysis of the problem and selection of such a solution.

In the ACID model each of the two players (countries) has two objectives, namely: the expenditures, and the sulfur deposition, to be minimized. Denoting the objectives by a_1 , a_2 for the first player and by b_1 , b_2 for the second one, respectively, the agreement set has been described by a set of linear inequalities presented in Figure 7. The description has been obtained for assumed forms of the cost functions and given parameters in deposition equations. The parameters have been assumed in such a way that the first player represents developing country with highly polluting technologies and very limited funds for the reducing program, while the second player represents highly developed country, with advanced technologies.

To see how the model is introduced into the system, first select the EDIT option and next select in a sequence the options : PLAYERS, CRITERIA and FORMULAE exiting each of them by pressing <F9> key. You will obtain respectively the screens presented in Figures 5 , 6 and 7.

In Figure 5 you can see the number of players (2) and their names (PLAYER1, PLAYER2). In Figure 6 the names of criteria, their description, status, units and status quo point are given. The criteria names are used in the description of the formulae defining the agreement set, as you can see in Figure 7. In the figure only part of the formulae is presented. To see all of the formulae use scrolling <Up, Down arrows > , <PgDn> and <PgUp> keys.

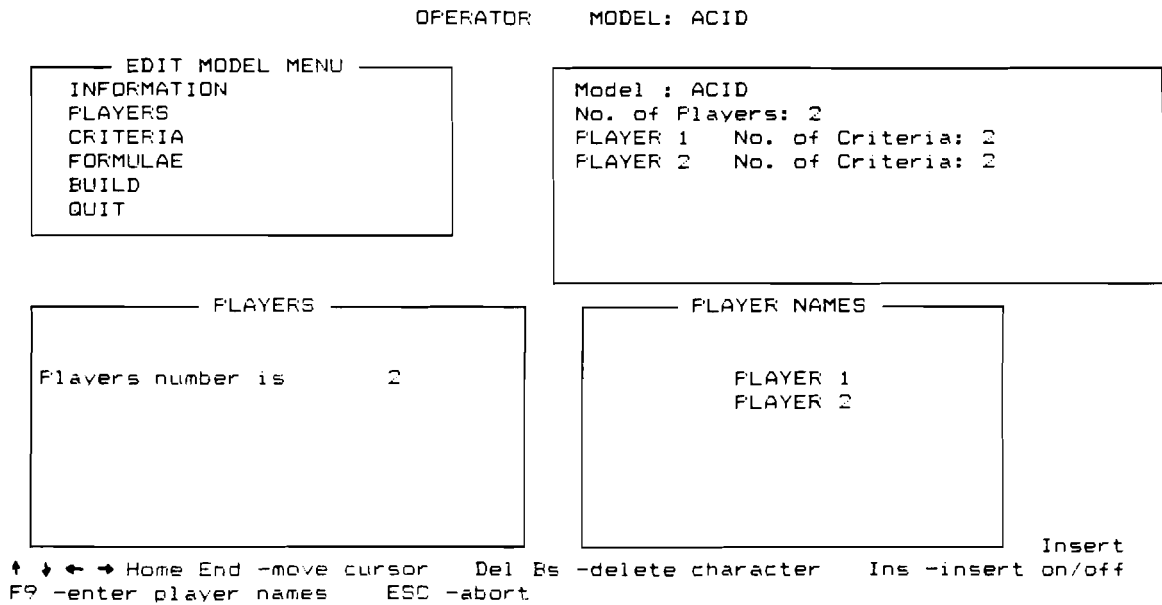


Figure 5

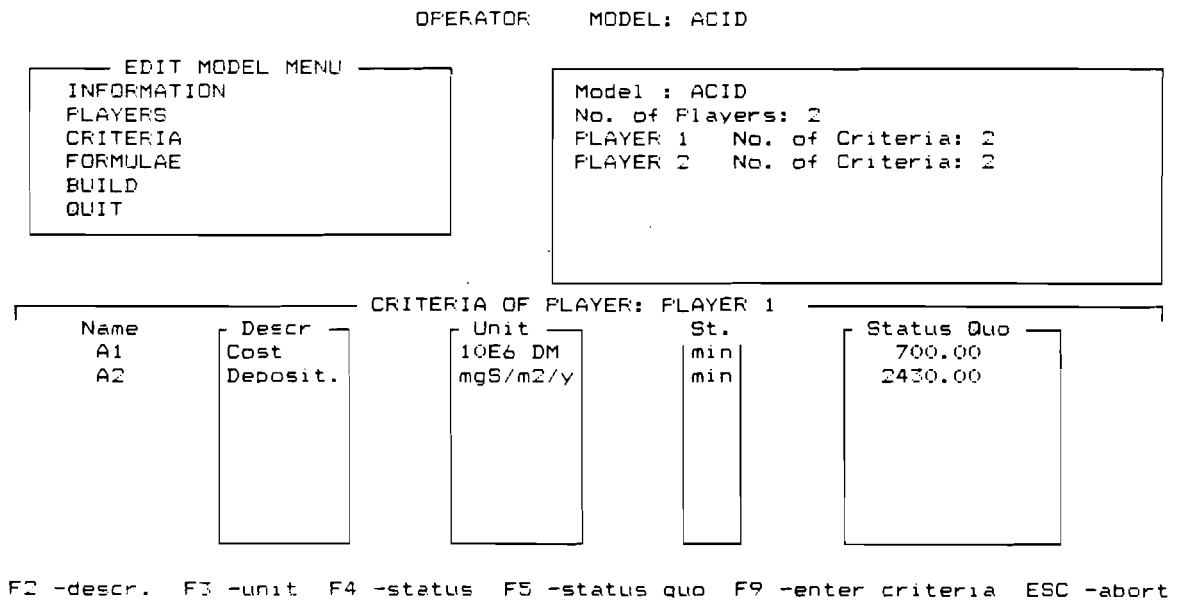


Figure 6

```

EDIT MODEL MENU
INFORMATION
PLAYERS
CRITERIA
FORMULAE
BUILD
QUIT

Model : ACID
No. of Players: 2
PLAYER 1   No. of Criteria: 2
PLAYER 2   No. of Criteria: 2

Line 8          FORMULAE
Col 1          Insert
f1=0.7-a1/1000; f2=3.0-b1/1000;
f3= 2.43-a2/1000; f4=1.75-b2/1000;
f5=a1/1000; f6=b1/1000;
f10=(a1+b1)/1000*(-0.27027)+1;
f11=(a1+b1)/1000*0.10813 + a2/1000*0.33685 + b2/1000*0.15158 -1;
f12=(a1+b1)/1000*0.11267 + a2/1000*0.17635 + b2/1000*0.27432 -1;
f13=(a1+b1)/1000*0.11945 + a2/1000*0.15468 + b2/1000*0.27671 -1;
f14=(a1+b1)/1000*0.13081 + a2/1000*0.07448 + b2/1000*0.32494 -1;

↑ ↓ ← → End Home -move cursor   Del Bs -delete character   PgUp PgDn -move page
~I/Y -insert/delete line   Ins -insert on/off   F9 -enter formulae   ESC -quit

```

Figure 7

Leave the model unchanged and quit the **EDIT** option.

Next, select the **BUILD** option of the **MODEL** menu. Wait please until the system has translated the model into the internal form and made the initial calculations.

Next, return to the **MAIN** menu and the start negotiation-mediation procedure by selection of the **NEGOTIATION** option.

Before starting the mediation, the system will ask you to specify the level of players' access to the information about the counterplayers. Press <F1> key (Help) to get detailed information about the possibilities provided by the system. Select the **LEVEL 2** if you want players to receive all the available information in the system about the actions of their counterplayers.

Now your screen will look like Figure 8.

It allows the players to take part in the negotiation procedure. From now on, you can play the role of one of the players or of the **OPERATOR**.

The negotiation procedure is performed in a number of iterations. At each iteration the players make their decisions in a sequence, once per iteration. The **OPERATOR** can observe and review the players results, and save the finished or interrupted session.

To continue the tutorial example select the **PLAYER1**. Type a password. The systems invokes the **NEGOTIATION** menu presented in Figure 9.

Select the **DECISION** option. Within this option you can test the nature of the bargaining problem by generation of a number of anticipated solutions, obtained for different confidence coefficients and reference points specified in your objective space and in the space of the counterplayers.

On the screen presented in Figure 10 you can see the **DECISION** menu in the top line and the first variant of anticipated solution in the table.

It has been calculated for the reference point defined according to the direction from the status quo to the ideal point. The table contains, apart from the anticipated solution (Ant. sol.), the following values: number of variant (Var.), status quo, solution obtained

```

      NEGOTIATION      MODEL: ACID      SESSION: NEW

      -----Iteration No 1-----
      Select player name
      PLAYER 1      PLAYER 2      OPERATOR
  
```

```

      Iteration No 1
      Decision done by:
  
```

↑ ↓ ← → -move bar ← -select player ESC -abort

Figure 8

```

      PLAYER: PLAYER1      MODEL: ACID      SESSION: NEW

      -----NEGOTIATION MENU-----
      INFORMATION
      DECISION
      VIEW
      PRINT
      QUIT
  
```

↑ ↓ Home End -move bar ← -select option F1 -help ESC -abort.

Figure 9

```

INFO  CONF_COEF  NEW_REF  VIEW_CNTR_FL  SELECT  QUIT
      DECISION  PLAYER: PLAYER1  MODEL: ACID  SESSION: NEW  Iter.: 1
Your confidence coefficient: 1.0000

```

Crit/St.	Var	Status quo	Prev. sol.	Ref. point	Ant. sol.	RA-utopia	Ideal
Cost 10E6 DM [min]	1	700.00	700.00	94.68	315.92	94.68	0.00
Deposit. mgS/m2/y [min]	1	2430.00	2430.00	1187.79	1641.80	1187.79	993.48

```

← → Home End -move bar  ← -select option  Tab -act. var.  ↑ ↓ -scroll var.
^PgUp ^PgDn -active crit. PgUp PgDn -scroll crit. ^G -graph F1 -help Esc -abort

```

Figure 10

in the previous iteration (Prev. sol.), reference point (Ref. point), RA-utopia point and ideal point. The status quo, the previous solution and the ideal point are constant within the analysis, while the other values depend on the confidence coefficient, on the reference point and on assumed actions of the counterplayer. The status quo and the previous solution are equal in the first round. The previous solution and the ideal point define reasonable bounds for the new reference points.

Using the **CONF_COEF** option you can modify the confidence coefficient. The lower the value of the coefficient means you have a more limited confidence on the future outcomes of the problem. There will be a greater number of the iterations in the mediation procedure. In our example take the value 0.3.

The **NEW_REF** option allows you to specify reference points and to generate different variants of anticipated solutions, depending on your preferences. Notice that there is one variant already calculated and presented on the screen, so you start from the variant two.

Let us assume that as the first player you prefer to obtain some reasonable decrease of both the expenditures and the sulfur depositions in comparison to the status quo. Select the **NEW_REF** option and type the reference for the cost and deposition (400.00 and 1100.00 respectively). This will be variant 2. The system asks if you accept the default assumptions on the counterplayer decision. (By default the system assumes the decisions of the counterplayers on the base of the previous round, in the case of the first round on base of the direction generated by the ideal point). Press Y (yes) to proceed further. Wait until the system has finished the calculations and has presented the results.

Test the next, third variant. Try to increase the cost and to decrease the deposition. Type the values 700.00 and 1000.00 respectively. Wait for results. The screen will look like Figure 11.

You can compare the generated variants in a graphical form by pressing <Ctrl G> key. Try it. You see the horizontal bars representing the improvements of the anticipated solution in comparison to the status quo. In the case of the maximized criterion, the bar

```

INFO  CONF_COEF  NEW_REF  VIEW_CNTR_FL  SELECT  QUIT
      DECISION  PLAYER: PLAYER1  MODEL: ACID  SESSION: NEW  Iter.: 1
Your confidence coefficient: 0.3000

```

Crit/St.	Var	Status quo	Prev. sol.	Ref. point	Ant. sol.	RA-utopia	Ideal
Cost	1	700.00	700.00	94.68	518.41	94.68	0.00
10E6 DM	2			400.00	609.36	397.85	
[min]	3			700.00	700.00	700.00	
Deposit.	1	2430.00	2430.00	1187.79	2057.34	1187.79	993.48
mgS/m2/y	2			1100.00	2028.14	1090.47	
[min]	3			1000.00	1999.04	993.48	

```

← → Home End -move bar  ← → -select option  Tab -act. var.  ↑ ↓ -scroll var.
^PgUp ^PgDn -active crit. PgUp PgDn -scroll crit. ^G -graph F1 -help Esc -abort

```

Figure 11

begins at the left hand side of the screen, in the case of the minimized, at the right hand side.

To analyze how the counterplayer decisions influence your outcomes, generate the variant 4 in the place of the variant 3, typing the same reference values as in the variant 2 but answer N (no) to the system question about the assumptions on the counterplayer decision. You will have a possibility to choose and to type counterplayer reference values, different than the system default values. The anticipated solution will be computed using your values for the counterplayer.

To look at the results of the simulated counterplayer actions, use the VIEW_CNTR_PL option. An example of the displayed screen is presented in Figure 12. The results are presented in two tables. The table on the left relates to the counterplayer and the one on the right, to your results. You see one-shot solutions. These are solutions that lay on the Pareto frontier of the agreement set.

Return to the DECISION menu pressing <F9> key. Now you should make your decision. Indicate the variant which represents your preferences and should be taken as the base in calculating the cooperative solution. Obviously, in a real decision analysis, you will generate a greater number of variants to be sure that the selected variant expresses your preferences. In this tutorial example select the second variant. To do this enter the SELECT option and using <Tab> key set the variant 2 to be the active variant (the active variant is highlighted). Press <Enter> key.

In the bottom help lines you can see keys that were not used in the example. Here is their description. The <up, down arrows> scroll the active variants, <Ctrl PgUp, Ctrl PgDn> set the active criterion, and <PgUp, PgDn> scroll the criteria. The scrolling of the variants makes it possible to display on the screen any three of the generated variants. The scrolling of the criteria is useful when the number of criteria of the particular player is greater than 4.

Quit the DECISION menu, and quit the NEGOTIATION menu. You will be back at the

```

INFO  CONF_COEF  NEW_REF  VIEW_CNTR_FL  SELECT  QUIT
      DECISION   PLAYER: PLAYER1  MODEL: ACID  SESSION: NEW  Iter.: 1
Counter player: PLAYER 2                                     Your results

```

Crit/St.	Var	Prev. sol.	Ref. point	Ideal	One shot	Crit/St.	One shot
Cost	1	3000.00	2313.16	1626.31	2564.19	Cost	315.92
10E6 DM	2		2313.16		2522.28	10E6 DM	489.85
[min]	4		2700.00		2728.25	[min]	493.79
Deposit.	1	1750.00	1422.91	1095.82	1542.46	Deposit.	1641.80
mgS/m2/y	2		1422.91		1522.50	mgS/m2/y	1498.33
[min]	4		1400.00		1432.96	[min]	1515.82

```

^P -next player  Tab -act. var.  ↑ ↓ -scroll var.  ← → -toggle player
^PgUp ^PgDn -active crit.  PgUp PgDn -scroll crit.  F9 -exit  Esc -abort

```

Figure 12

screen presented in Figure 8. Select the **PLAYER2**. Next select the **DECISION** option in the **NEGOTIATION** menu. You will obtain the screen similar to the screen of the **PLAYER1** presented in Figure 9. Perform the interactive analysis in the same way as for the **PLAYER1**.

Assume that the **PLAYER2** has less limited confidence in the future outcomes than the **PLAYER1**. Describe his confidence with the coefficient equal to 0.4.

Next, type the reference values for the objectives of this player. The **PLAYER2**, representing highly developed country is interested mainly in a decreasing of the sulfur deposition. He decides to have the cost closely to the status quo level. Generate two variants for this player. Type the reference of the second variant on the level 2800.0, 1400.0 for the cost and the deposition respectively. This will be the variant 2. Next create the variant 3 with the reference values 3000.0, 1200.0 respectively. In both cases accept the default values for the counterplayer decision. You will obtain the screen presented in Figure 13.

Select the second variant as the preferable one. Quit the **DECISION** option and the **NEGOTIATION** menu.

Wait until the system has calculated the cooperative solution of the iteration. Now you are ready to start the next iteration. You see the screen presented in Figure 8.

Select **PLAYER1** and press the <Enter> key. You will invoke the **NEGOTIATION** menu. Before making a decision for the second iteration you can look at the first iteration, results selecting the **VIEW** option. Try it. You will see the screen presented in Figure 14.

Return to the **NEGOTIATION** menu and select the **DECISION** option. Follow the actions of **PLAYER1** presented in Figure 15 and select the variant 3. Note that the confidence coefficient has been assumed on the level of 1.000. Next quit the **DECISION** option and **NEGOTIATION** menu.

Select **PLAYER2**, next the **DECISION** menu and follow the actions of **PLAYER2** presented in Figure 16. Select the variant 3 as the preferable variant, quit the **DECISION** and the **NEGOTIATION** menu.

The system will calculate the final, efficient cooperative solution, proposed to the

INFO CONF_COEF NEW_REF VIEW_CNTR_PL SELECT QUIT
 DECISION PLAYER: PLAYER2 MODEL: ACID SESSION: NEW Iter.: 1
 Your confidence coefficient: 0.4000

Crit/St.	Var	Status quo	Prev. sol.	Ref. point	Ant. sol.	RA-utopia	Ideal
Cost 10E6 DM [min]	1	3000.00	3000.00	2313.16	2725.26	2313.16	1626.31
	2			2800.00	2882.46	2706.15	
	3			3000.00	3000.00	3000.00	
Deposit. mgS/m2/y [min]	1	1750.00	1750.00	1422.91	1619.16	1422.91	1095.82
	2			1400.00	1544.30	1235.76	
	3			1200.00	1488.33	1095.82	

← → Home End -move bar ← -select option Tab -act. var. ↑ ↓ -scroll var.
 ^PgUp ^PgDn -active crit. PgUp PgDn -scroll crit. ^G -graph F1 -help Esc -abort

Figure 13

VIEW PLAYER: PLAYER1 MODEL: ACID SESSION: NEW Iter.: 2
 Player: PLAYER 1 Iteration: 1 Session not finished
 Confidence coefficients joint: 0.3000 assumed by player: 0.3000

Criteria names	Status	Units	Status quo	Previous agr. point	Agreement point	One-shot solution	Ideal point
Cost	min	10E6 DM	700.00	700.00	609.36	495.29	0.00
Deposit.	min	mgS/m2/y	2430.00	2430.00	2028.14	1522.44	993.48

Criteria	St.	Graphical representation of results					
Cost	min						
Deposit.	min						

← → -scroll iter. ^PgUp ^PgDn -act. crit. PgUp PgDn -scroll crit.
 ^C -counter players F9 -exit ESC -abort

Figure 14

```

INFO  CONF_COEF  NEW_REF  VIEW_CNTR_PL  SELECT  QUIT
      DECISION  PLAYER: PLAYER1  MODEL: ACID  SESSION: NEW  Iter.: 2
Your confidence coefficient: 1.0000

```

Crit/St.	Var	Status quo	Frev. sol.	Ref. point	Ant. sol.	RA-utopia	Ideal
Cost 10E6 DM [min]	1	700.00	609.36	397.85	490.77	418.40	0.00
	2			500.00	548.33	515.98	
	3			550.00	574.95	557.90	
Deposit. mgS/m2/y [min]	1	2430.00	2028.14	1090.47	1502.43	1181.59	993.48
	2			1000.00	1454.43	1150.27	
	3			1000.00	1432.23	1136.82	

```

← → Home End -move bar  ← -select option  Tab -act. var.  ↑ ↓ -scroll var.
^PgUp ^PgDn -active crit. PgUp PgDn -scroll crit. ^G -graph F1 -help Esc -abort

```

Figure 15

```

INFO  CONF_COEF  NEW_REF  VIEW_CNTR_PL  SELECT  QUIT
      DECISION  PLAYER: PLAYER2  MODEL: ACID  SESSION: NEW  Iter.: 2
Your confidence coefficient: 1.0000

```

Crit/St.	Var	Status quo	Frev. sol.	Ref. point	Ant. sol.	RA-utopia	Ideal
Cost 10E6 DM [min]	1	3000.00	2911.84	2706.15	2803.88	2738.00	1626.31
	2			2500.00	2726.63	2617.68	
	3			2800.00	2863.41	2833.00	
Deposit. mgS/m2/y [min]	1	1750.00	1595.73	1235.76	1406.80	1291.50	1095.82
	2			1250.00	1440.24	1348.79	
	3			1100.00	1381.03	1246.25	

```

← → Home End -move bar  ← -select option  Tab -act. var.  ↑ ↓ -scroll var.
^PgUp ^PgDn -active crit. PgUp PgDn -scroll crit. ^G -graph F1 -help Esc -abort

```

Figure 16

players as a mediation solution.

Try to play the role of OPERATOR to review the session results selecting VIEW option in the OPERATOR menu, or to print the results using PRINT option.

MCBARG MODEL: ACID SESSION: ACID2Y 9/ 7/1990-13: 0

PLAYER: PLAYER1

```

I-----I
I Criteria names I Cost I Deposit. I
I Units I 10E6 DM I mgS/m2/y I
I Status I min I min I
I-----I
I Status Quo I 700.00 I 2430.00 I
I Ideal Point I 0.00 I 993.48 I
I-----I
I Agreement point I I I
I at iteration: 1 I 609.36 I 2028.14 I
I 2 I 575.35 I 1439.11 I
I-----I

```

PLAYER: PLAYER2

```

I-----I
I Criteria names I Cost I Deposit. I
I Units I 10E6 DM I mgS/m2/y I
I Status I min I min I
I-----I
I Status Quo I 3000.00 I 1750.00 I
I Ideal Point I 1626.31 I 1095.82 I
I-----I
I Agreement point I I I
I at iteration: 1 I 2911.84 I 1595.73 I
I 2 I 2859.74 I 1364.78 I
I-----I

```

Session finished

Figure 17

A summary printing of the session ACID2Y.SES is presented in Figure 17. Observe that at the final solution PLAYER1 has obtained a reasonable decrease, in comparison to the status quo, of both - the cost and the deposition levels, while PLAYER2 has obtained the cost and the deposition levels relevant to the assumed preferences - large decrease of the deposition level under costs close to the status quo.

The results can be reviewed and printed by any of the players (VIEW and PRINT options of the NEGOTIATION menu.

Quit the OPERATOR menu, not saving the session. The session of this tutorial example is already saved in the ACID2Y.SES file.

Quit the MAIN menu to leave the system.

5 Technical information

The program is distributed on a diskette that should be installed on an IBM PC compatible computer. This diskette contains the following files:

- MCBARG.EXE — binary code of the program,
- INFOSYS.DAT — file of records containing information presented in the program by INFO option,
- HELPSYS.DAT — file of records containing information presented in the program by HELP option,

- **ACID.MOD**, **AGRICO.MOD** — files containing the illustrative examples of bargaining problems (description of **AGRICO.MOD** - see Bronisz, Krus, Lopuch, 1988),
- **ACID2Y.SES** — file containing the illustrative session.

The program is activated by the command: **MCBARG**. It automatically recognizes one of the following graphic cards: **HERCULES**, **CGA**, **EGA**.

The program enables a user to create new models (sessions) of bargaining problems and to save the models (sessions) on the active disk. Default extension of the files containing the models is **.MOD** (the session - **.SES**). During a session with the system the following auxiliary files are generated on the disk: **BACKUP.DDD**, **BACKUP.SSS**. They are erased after a session.

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