WORKING PAPER

DIALOG SYSTEM FOR MODELING MULTIDIMENSIONAL
DEMOGRAPHIC PROCESSES

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1. INTRODUCTION

A growing understanding of the importance of demographic processes in social and economic development places greater demands on the quality of demographic research and on the adequacy and convenience of tools used in the analysis of a population's characteristics.

Multistate population models recently became popular in the study of many aspects of demographic transitions, such as migration, marriage, changes of health status, social status, occupation, etc. [1,2].

Computer programs and software packages were developed to realize such models [3,4]. However, most of these allow analysis of systems only when fertility, mortality, or transition coefficients do not depend on time. Some authors have overcome this drawback [5,6] and have created the opportunity to analyze alternative evolutions of the system under various scenarios of natural and mechanical reproduction of the population. However, these programs are not always appropriate for use by the many demographers and health specialists who are not deeply involved in computer modeling. The software is often not flexible enough to enable choices of and changes in the variables that determine the scenarios, the representation of the results, and the control of modeling itself.

The most important disadvantage of these packages is the inability to communicate interactively with the model. As experience shows, interactively working with computers essentially reduces the time spent on model design and debugging. It also creates additional opportunities for model analysis.

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Thus, there is a necessity to create a user-friendly system that allows a more effective analysis of demographic processes.

In this paper an interactive system that uses the multistate demographic models is described. The system provides the opportunity to prepare scenarios, change coefficients of the model during the modeling procedure, and present intermediate results. The paper uses some results of research conducted at VNIISI and at IIASA: namely, the design of the man-machine modeling system [7] and the modeling of multistate demographic processes [3,4,8,9].

2. REQUIREMENTS FOR THE DIALOG SYSTEM OF MODELING

The first version of the interactive system was based on the following main requirements.

(1) The dialog system should be simple in that the command language should be as close to natural as possible. Since the system is oriented toward non-specialists in computer science, the leading role in the dialog should be played by the system itself. The user should only answer simple questions or select instructions from the menu.

(2) An opportunity to control the modeling procedure should be provided; that is, one should have the opportunity to stop modeling, change the control variables, and then start modeling again.

(3) Visual display of the modeling results should be provided. One should be able to obtain tables and graphs (on graphic display, printer, or plotter) during the modeling.

(4) The system should provide opportunities for flexible scenario setting. For demographic and medical demographic models the opportunity to set scenarios for such variables as age-specific mortality, age-specific fertility, crude birth rates, transition intensities, etc., should be provided. The system should also provide the opportunity to set the functions in terms of tables, and contain some standard functional forms, such as exponential, linear, etc.

(5) The system should enable the user to change the structure of the model or incorporate a new one from the class of discrete-time Markov processes. The opportunity to change dialog in accordance with the changes in model type should be provided.

(6) The opportunity to easily transfer the model from one computer to another should be provided.

3. DESCRIPTION OF THE MODEL

A detailed mathematical description of the multistate population dynamics is given by Rogers [9,10]. It has been shown that the dynamic of the population can be described by the equation

$$K(t + h) = G(t)K(t)$$

where K characterizes the population according to age groups and different states at times t and $t + h$, h is the time interval as well as the age interval, and G is the growth matrix:

$$G = \begin{bmatrix} 0 & 0 & B(\alpha - h) & \cdots & B(\beta - h) & \cdots & 0 & 0 \\ S(0) & 0 & & & & & & \cdot \\ 0 & S(h) & & & & & & \cdot \\ \cdot & \cdot & & & & & \cdot & \cdot \\ \cdot & \cdot & & & & & \cdot & \cdot \\ \cdot & \cdot & & & & & \cdot & \cdot \\ 0 & 0 & & & & & S(z-h) & 0 \end{bmatrix}$$

The first row of matrix G consists of the matrices $B(x)$,

$$B(x) = (\frac{h}{4}) \, C \, [P(0) + I][F(x) + F(x + h)S(x)]$$

where $F(x)$ is the diagonal matrix for birth rates of people aged x to $x + h$ years old in different states. The P matrix contains the survival probabilities from age x until $x + h$. The entries under the main diagonal of the G matrix determine the survival coefficients,

$$S(x) = [I + P(x + h)]P(x)[I + P(x)]^{-1}$$

The transition probabilities are calculated in the same manner as for increment-decrement life tables. At first the observed coefficients are grouped into the matrix:

$$M(x) = \begin{bmatrix} [M_{d1}(x) + \sum_{j \neq 1} M_{j1}(x)] & -M_{12}(x) & \cdots & -M_{1n}(x) \\ -M_{21}(x) & [M_{d2}(x) + \sum_{j \neq 2} M_{j2}(x)] & & -M_{2n}(x) \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ -M_{n1}(x) & -M_{n2}(x) & & [M_{dn}(x) + \sum_{j \neq n} M_{jn}(x)] \end{bmatrix}$$

where $M_{id}(x)$ is the age-specific annual death rate in state i, and $M_{ij}(x)$ is the age-specific annual transition rate from state j to state i.

The probability matrix P is calculated as follows

$$P(x) = [I + \frac{h}{2}M(x)]^{-1}[I - \frac{h}{2}M(x)]$$

The C matrix determines the state in which newborns appear in connection with their parents' state. Thus, the rows of the C matrix represent the states of the newborns and the columns represent the states of the parents. If, say, $C(i,j) = 1$ then the parents are in state j and the children will appear in state i. The C matrix satisfies the usual probabilistic constraints: $C(i,j) \geq 0$, $\sum_j C(i,j) = 1$.

Just [11] has shown that to complete the female dominant two-sex model a diagonal matrix X^f has to be defined. Its elements are the ratios of males to females born by a woman in each state. Usually these ratios are identical. Thus

$$X^f = \begin{bmatrix} s_1^{-f} & \cdots & & & & 0 \\ & \ddots & & & & \\ & & s_j^{-f} & & & \\ & & & \ddots & & \\ 0 & \cdots & & & & s_n^{-f} \end{bmatrix}$$

where

$$s_j^{-f} = 1/[1 + (b_j^m/b_j^f)]$$

and b_j^m and b_j^f denote the number of male and female births. For the female projection the first row of the growth matrix is given by elements

$$B^f(x) = (\frac{h}{4})CX^f[P^f(0) + I][F(X) + F(x+h)S^f(x)]$$

The superscript f indicates that the survivorship proportions and probabilities of female population are used. The projection of the male population is performed in two steps. First the total (male and female) population at exact age 0 is calculated by

$$K^*(0) = \sum_X [F(x) + F(x+h)S^f(x)]^t K^f(x)$$

$K^*(0)$ is now input to the projection of males. The male population in the first age group at time $t+h$ can easily be derived by means of

$$t+h K(0)^m = CX^m [P^m(0) + I]K^{\cdot}(0)$$

where the elements s_j^{-m} of X^m are $1 - s_j^{-f}$. The other age groups are carried forward by

$$t+h K^m(x+h) = S^m(x)^t K^m(x)$$

for $h \leq x \leq n -h$, where n stands for the last age group.

4. THE STRUCTURE OF THE INTERACTIVE SYSTEM

The block scheme for the dialog system, which satisfies most of the numerated requirements, is represented in Figure 1. The user starts the system by typing the name of the loading module SPAT. The rest of the dialog with the system is continued in the **menu** mode. The job control block asks the user which of the blocks is to have control:

- (1) Initialization.
- (2) Modeling.
- (3) Scenario setting.
- (4) Result representation.

The user types the number and the respective block controls the system.

4.1. Model Initialization

During model initialization the file with the initial data is read. This file should be prepared in a particular form, described in the Appendix A.1 and A.2. The model initialization procedure is necessary in the following cases:

(a) Before starting work with a model.

(b) Before a new start of the modeling procedure (starting a new scenario, for example).

(c) When choosing a new type of model (medical demographic or demographic) or a new model (another country or region) without exiting the system.
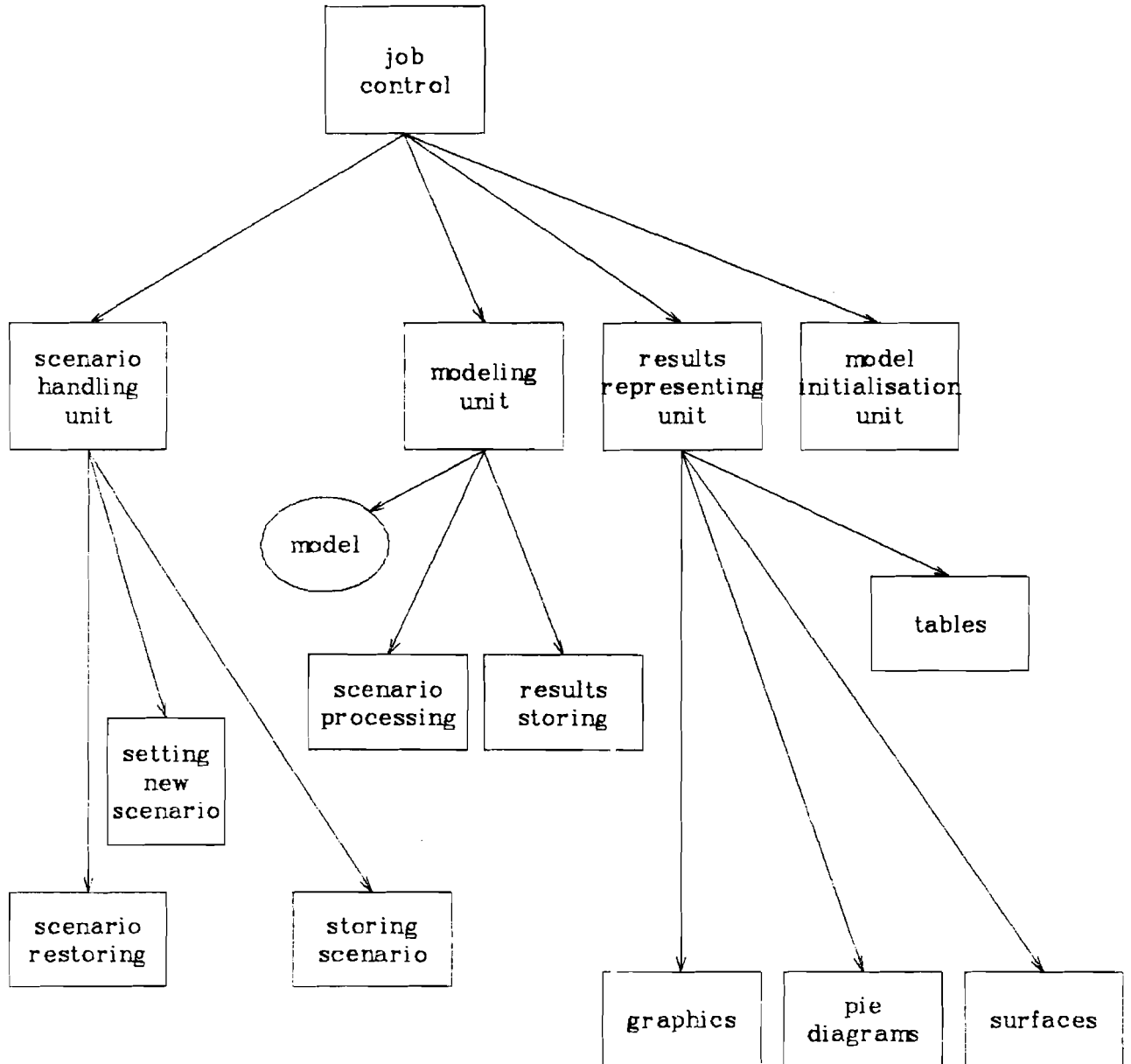
Figure 1.   Structure of the dialog system.

4.2. Scenario Setting

The system provides flexible and convenient setting of the control variables. These variables, which determine the scenario, can be set as a table in the interactive mode, when some fixed time points correspond to the values of the scenario variables or as a function of time.

Any model's parameter or exogenous variable can be chosen as a scenario variable, since the scenario determines the number of given variables. During the modeling procedure the values of the scenario variables are calculated for any time in the scenario block, based on information determined by the user in the block for scenario setting. If for some variable the scenario is not set, its value is specified as a default value (calculated from initial data) and is unchangeable during the process of modeling.

A scenario setting block allows the user to:

(1) Set the scenario on fertility.

(2) Set the scenario on mortality.

(3) Set the scenario on migration or transitions between states.

(4) Set the scenario by a variable name.

(5) Save the scenario.

(6) Read a scenario from the file.

4.2.1. Scenario Setting for Fertility, Mortality, and Migration

Scenarios on fertility and mortality are determined for one or several states (regions). The system asks the state of departure and the state of destination for setting transition scenarios.

The gross fertility (GRRN), mortality (GDRN), and migration (GMRN) rates are taken as scenario variables. In modes 1, 2, and 3 when the nonnegative values of GRRN, GDRN, and GMRN are set, only the area under the age-specific rates of fertility, mortality, and migration (RATF, RATD, and RATM) changeable; the shape of the age-specific rates is unchangeable.

For negative values, GRRN, GDRN, and GMRN act as switches, which is discussed later.

The scenario variable can have up to 10 values. The time and the values are specified as follows:

T1   Y1

T2   Y2

T3   Y3

During simulation the values of the scenario variables in between the given points are calculated using linear interpolation.

If the variable is specified as a function of time, the values of the respective coefficients that determine this function are determined. Note that each new setting of the values for some scenario variable cancels values already specified.

4.2.2. Setting a Scenario by the Variable Name

The system provides an opportunity for scenario setting according to the variable name. For this purpose, the user should have the list of the variable names (identifiers) (Appendix A.4). Let, for instance, the user know that the identifier of the variable fertility coefficient for the first region in the list of regions in the model is GRRN(1). Then, being in mode 4 one should type the name GRRN(1) and, following the dialog, type the desirable values.

In this case there is the opportunity to set age-specific fertility, mortality, and transition rates. Knowing the respective identifier one can determine the scenario value of the coefficient for given states and age groups. If at the same time the value of the scenario variable for a gross rate, say, fertility GRRN, is set positive, then the area under the curve RATF will change and will equal the new value, but the form of the curve will not change. If GRRN is negative, then it will no longer be a gross reproduction rate, but act as a switch.

In this case no normalization and age-specific coefficients will stay the same, except for those that the scenario has specified. The area under the age distribution RATF will change. Note that the initial values of gross rates are calculated according to initial patterns of fertility, mortality, and migration.

4.2.3. Using the Mode of Scenario Setting by the Variable Name for Model Debugging

When working with the model it is sometimes necessary to look at the current value of variables the representation of which is not provided in the program. The mode of scenario setting by the variable name can be used for this purpose, since during scenario setting in this mode the current value of this variable is printed first. Then the user decides whether to leave the variable unchanged or set it to a new value. Thus, to use this mode for model debugging, one needs to know only the identifiers of the variables, which are given in the Appendix A.4.

4.2.4. Saving the Scenario

Creation of the scenario can be time-consuming, especially if the number of control variables is high. Since one sometimes needs to work with the same scenario again, the scenario can be saved. The user should provide the name of the scenario in order to do this, and the information about the scenario will be written to a disk file.

4.2.5. Reading the Scenario from the File

To work with a scenario that has already been created by the user or has been saved from the dialog system, there is the opportunity to read the scenario from the file. For this purpose, the user types the name of the file where the scenario is written. The file with the scenario is prepared according to the following rules:

a) the string is read as a comment if the first character is 'c';

b) the scenario variable is defined as the following function:

$$<\text{variable name}> = \text{TABLE}(t_1, Y_1, t_2, Y_2, ..., t_n, Y_n)$$

where, $t_1, t_2, ..., t_n$ are time points, $Y_1, Y_2, ..., Y_n$ are values of the scenario variable;

c) the string can be transferred at any place;

d) a few scenario variables can be defined in the file;

e) only one scenario can be defined in the file.

After the scenario has been read, the user can deal with it as if it had just been created: one can add the new variable values, change the values of the old variables, etc.

4.3. Modeling

The simulation is performed in the modeling block. Modeling can be done in several time intervals. When the system asks "ENTER TIME SPAN", the last year of modeling should be specified by the user. If the modeling procedure is started after the model initialization, then the time from the file used for initialization is taken as the initial time for the modeling interval. The modeling step coincides with the width of the age group. The modeling interval can consist of one or several steps.

During the modeling procedure the user has the following opportunities:

(1)   After completing the modeling process for the first time interval, one can continue modeling. For this purpose one should specify the end point of the new time interval. The end point of the previous time interval is considered as the initial point for a new interval of modeling.

(2)   One can represent the results of modeling after each specified modeling interval (dumping).

(3)   One can obtain result representation after each step of the modeling process.

(4)   One can change the values of the scenario variables and introduce new scenario variables.

(5)   One can stop modeling and start modeling again with a new model without exiting the dialog system.

4.4. Representation of Modeling Results

A representation block realizes the output of the produced results during the process of modeling (printing data during the run), as well as after completion of the modeling interval (dumping data).

During the modeling process information is represented in terms of tables and is written into the file associated with unit number 2 after each step (not the modeling interval). The list of tables is given in the menu. When dumping data, the result appears on the screen.

In order to achieve more independence from the available hardware environment (the size of the terminal screen or the width of the printer paper), a special table generator was developed. This helps to easily adapt the representation form for the results of modeling to the particular type and configuration of the computer. It also allows deletion of constraints related to the number of states and age groups in the model, which usually produce problems in representation of the results.

After completing the modeling procedure the results can be represented as:

(1) Current values of the demographical variables in the form of tables.

(2) Piecharts of the population structure at the current time.

(3) A histogram of the age-specific population structure in each state (group) at the current time.

(4) The population size in each state (group) starting from the initial time of modeling until the current year.

(5) A new version of the system will include graphic representation of the population as a function of time and age using a three-dimensional plot.

The graphic information can be represented either by graphic display or plotter.

5. REALIZATION

The dialog system was created for use on the VAX 11/780. However, at each stage of its design, efforts were developed to make the system as machine independent as possible. The programming language used is FORTRAN 77, which minimizes the effort required to transfer this system to another computer.

Programs for the graphic representation of results are machine-dependent. For instance, IIASA uses the NEWPLOT system. During modeling the results are written in some auxilliary data file. The call to the NEWPLOT comes from the programs of the dialog systems written in FORTRAN. The NEWPLOT system uses a command file, which should be prepared beforehand, reads the data from the auxilliary data file, and plots the respective graphs. Control is then transferred back to the dialog system. Thus, the user should create the special command file for the NEWPLOT system, which then starts execution from the dialog system. In the new version of the dialog system, formation of the command file for the NEWPLOT sys-

tem is realized automatically from the main system. The generalized version of the system, which takes into account sex composition of the population, is now being developed for PCs.

Appendixes

A.1 Input Data File

Before using the system the user should prepare the initial data file. The data are read in free format from the device with a logical number of 4. The name of the input file is requested by the system at the beginning of the dialog. This file contains the following information:

(1) The title of the data file — one record containing information about this data file (the form of the note is arbitrary).

(2) The model's parameters.

NA — the number of the age groups, NA ≤ 18 in this version of the model.

NSEXES — the number of sexes (1 or 2).

NR — the number of regions or states, NR ≤ 15 in this version.

NY — the size of the age cohort, usually NY = 1 or NY = 5.

NU — the number of strings in the title of the system.

INIT — the initial year of modeling.

NG — switch of the model type.

SEXRAT — the ratio of female to male newborns.

NAGE(NA+1) — array of age boundaries.

NG = 0 corresponds to the model type in which a newborn appears in the same state as the parents. In this case the C matrix is identical. When the switch NG = 1 this corresponds to the model where all newborns appear in the same state.

NDAT — switch of the initial data type.

NDAT = 1 corresponds to the case when fertility, mortality, and migration are given in absolute numbers. If NDAT = 2, the coefficients of fertility, mortality, and migration are given.

(3) The title of the system. This is the number of records that will be seen on the display after all data from the file have been read.

(4) The name of the country or the system of the states (groups).

(5) Data. For each state (group) should be given:

the data for state 1,

the data for state 2,

the data for state NR.

The data for each state includes the following information:

(a) The name of the region or state, which may contain up to 8 symbols.

(b) The population's age structure at time INIT.

(c) Fertility. The age-specific pattern is specified. When NDAT = 1 the births are given in absolute numbers. When NDAT = 2 the birth rates are specified.

(d) Mortality — the age-specific mortality is specified. When NDAT = 1 it is given in absolute numbers. If NDAT = 2 the mortality rates are specified.

(e) Transitions from one given state to another. When birth and death are specified in absolute numbers, then the age structure of transitions should also be specified in terms of absolute numbers. If birth and death are specified by rates, then age-dependent transition rates should also be specified.

(f) The last sentence in the data file is the word END.

A.2. Example of the Initial Data File

Strings which start with the symbol * are comments given to facilitate understanding of the structure of the initial data file. In real initial data files, all such comments are prohibited.

* 1. The title of the data file.

 country 1:   -   2 regions   -   two sexes: male,female

* 2. Model's parameters.
* NA NSEXES NR NY NU INIT NG NDAT SEXRAT

 16   2   2   5   4 1975 0   1   1.000

* 3. Age intervals for which data are given

 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

* 4. Title in the system.

   MULTIREGIONAL POPULATION SIMULATION
            for
      hypothetical country
      starting year 1975

* 5. Name of the country or the states of the system.

 COUNTRY

* 6. Data for the first state.

     *a) Name of the state.

 NORTH

   *   Data for female.

     *b)Population age structure.

130449.	164503.	204645.	189898.	188590.	116643.	124046.
168270.	140364.	117915.	96209.	66299.	95490.	100051.
84113.	97898.					

     *c)Fertility.

| 0. | 0. | 1. | 9100. | 23550. | 9452. | 3896. | 987. | 396. |
| 3. | 0. | 0. | 0. | 0. | 0. | 0. | | |

     *d)Mortality.

| 519. | 76. | 51. | 167. | 196. | 119. | 172. | 313. | 423. |
| 501. | 676. | 651. | 1765. | 3033. | 4544. | 12783. | | |

     *e)Transitions from 1 to 1.

| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |

     *f)Transitions from 1 to 2.

| 337. | 188. | 130. | 270. | 876. | 421. | 228. | 150. | 75. |
| 51. | 31. | 11. | 34. | 35. | 22. | 38. | | |

*   Data for male.

*g)Population age structure.

130449.	164503.	204645.	189898.	188590.	116643.	124046.
168270.	140364.	117915.	96209.	66299.	95490.	100051.
84113.	97898.					

*h)Mortality.

919.	96.	81.	267.	296.	219.	272.	413.	523.
601.	776.	851.	1965.	4033.	5544.	15783.		

*i)Transition from 1 to 1.

0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.

*j)Transition from 1 to 2.

337.	188.	130.	270.	876.	421.	228.	150.	75.
51.	31.	11.	34.	35.	22.	38.		

* 7. Data for the second state.

SOUTH

62653.	79009.	92259.	73156.	72651.	66688.	90215.
100196.	76735.	62934.	48528.	38995.	56860.	64747.
52249.	60299.					

0.	0.	2.	3428.	9451.	5840.	3426.	905.	189.
7.	0.	0.	0.	0.	0.	0.		
221.	30.	30.	53.	69.	62.	112.	164.	212.
287.	357.	453.	1171.	2194.	3005.	8338.		
108.	83.	99.	105.	216.	132.	87.	60.	36.
19.	11.	4.	18.	14.	9.	20.		
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.		

62653.	79009.	92259.	73156.	72651.	66688.	90215.
100196.	76735.	62934.	48528.	38995.	56860.	64747.
52249.	60299.					

221.	30.	30.	53.	69.	62.	112.	164.	212.
287.	357.	453.	1171.	2194.	3005.	8338.		
108.	83.	99.	105.	216.	132.	87.	60.	36.
19.	11.	4.	18.	14.	9.	20.		
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.		

A.3 Example of Dialog: Underlined Symbols are Introduced by User

INTERACTIVE SYSTEM

for Multistate Population Simulation

Version 1.00

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to continue press <return>:

0 — exit
1 — model initialization
2 — modelling
3 — scenario setting
4 — results presentation

to start or to restart model you must first initialize it

enter number:1

enter, please, name of the file with data
for the country you want to deal with: country.dat

MULTIREGIONAL POPULATION SIMULATION
for
hypothetical country
starting year 1975

to continue press <return>:

0 — exit
1 — model initialization
2 — modelling
3 — scenario setting
4 — results presentation

enter number:3

```
0 - exit
1 - fertility (grr)
2 - mortality (gdr)
3 - transitions and morbidity (gmr)
4 - varible by name
5 - save scenario
6 - read scenario from the file

enter number:1


1 - NORTH
2 - SOUTH

3 - exit to previous level


you are setting fertility scenario
enter region number:1

there was no scenario set for this variable
the default value is  1.4698

        1 - do not change default value
        2 - set new scenario

enter number:2

enter new scenario in format:

    time        value   (to end press ^z and then <return>)
1980  1.7
1985  1.8
^Z


0 - exit
1 - fertility (grr)
2 - mortality (gdr)
3 - transitions and morbidity (gmr)
4 - varible by name
5 - save scenario
6 - read scenario from the file

enter number:0

0 - exit
1 - model initialization
2 - modelling
3 - scenario setting
4 - results presentation

enter number:2
```

```
enter end of time interval:1990

current time - 1980
current time - 1985
current time - 1990


0 - exit
1 - model initialization
2 - modelling
3 - scenario setting
4 - results presentation

enter number:4


0 - exit
1 - printing data during run
2 - dumping data

enter number:2


0 - exit
1 - age-specific rates
2 - gross rates
3 - expectancies
4 - births, deaths
5 - transition flows
6 - indices of labory activity
7 - summary table
8 - population distribution
9 - percentage population distribution
10- graphics


enter number:8

enter sex:
1 - female, 2 - male, 3 -total
enter number:2
```

population distributions by age and regions
variant: male   year: 1990

		NORTH	SOUTH	COUNTRY
	0	155075.	65460.	220535.
	5	147895.	63967.	211862.
	10	119060.	59686.	178746.
	15	125832.	63020.	188852.
	20	159963.	80531.	240494.
	25	195148.	96560.	291708.
	30	178302.	78842.	257144.
	35	177265.	77129.	254395.
	40	110612.	66918.	177530.
	45	117336.	87764.	205100.
	50	156183.	95139.	251322.
	55	125737.	70186.	195924.
	60	99460.	54082.	153543.
	65	72265.	37571.	109836.
	70	40498.	25305.	65803.
	75	65611.	49526.	115138.
total		2046244.	1071686.	3117930.

to continue press <return>:

```
0 - exit
1 - age-specific rates
2 - gross rates
3 - expectancies
4 - births, deaths
5 - transition flows
6 - indices of labory activity
7 - summary table
8 - population distribution
9 - percentage population distribution
10- graphics


enter number:3

enter sex:
1 - female, 2 - male, 3 -total
enter number:1
```

```
                life expectancies
        variant: female    year:   1990
```

		NORTH	SOUTH	
NORTH		67.010	3.068	
SOUTH		4.180	67.780	
total		71.189	70.848	

to continue press <return>:


```
0 - exit
1 - age-specific rates
2 - gross rates
3 - expectancies
4 - births, deaths
5 - transition flows
6 - indices of labory activity
7 - summary table
8 - population distribution
9 - percentage population distribution
10- graphics
```

enter number:2

enter sex:
1 - female, 2 - male, 3 -total
enter number:1


```
                  gross rates
        variant: female    year:   1990
```

		NORTH	SOUTH	
gross fert. rate		1.800	1.571	
gross mort. rate		1.342	1.431	
gr. mob.tot.rate		0.098	0.070	
NORTH		0.000	0.070	
SOUTH		0.098	0.000	

to continue press <return>:

```
0 - exit
1 - age-specific rates
2 - gross rates
3 - expectancies
4 - births, deaths
5 - transition flows
6 - indices of labory activity
7 - summary table
8 - population distribution
9 - percentage population distribution
10- graphics


enter number:10


0 - exit
1 - population structure in %
2 - age-specific fertility per 1000
3 - age-specific mortality per 1000
enter number:2

enter sex:
1 - female, 2 - male, 3 -total
enter number:1


0 - exit to previous level
1 - NORTH
2 - SOUTH
3 - COUNTRY
--->2
```
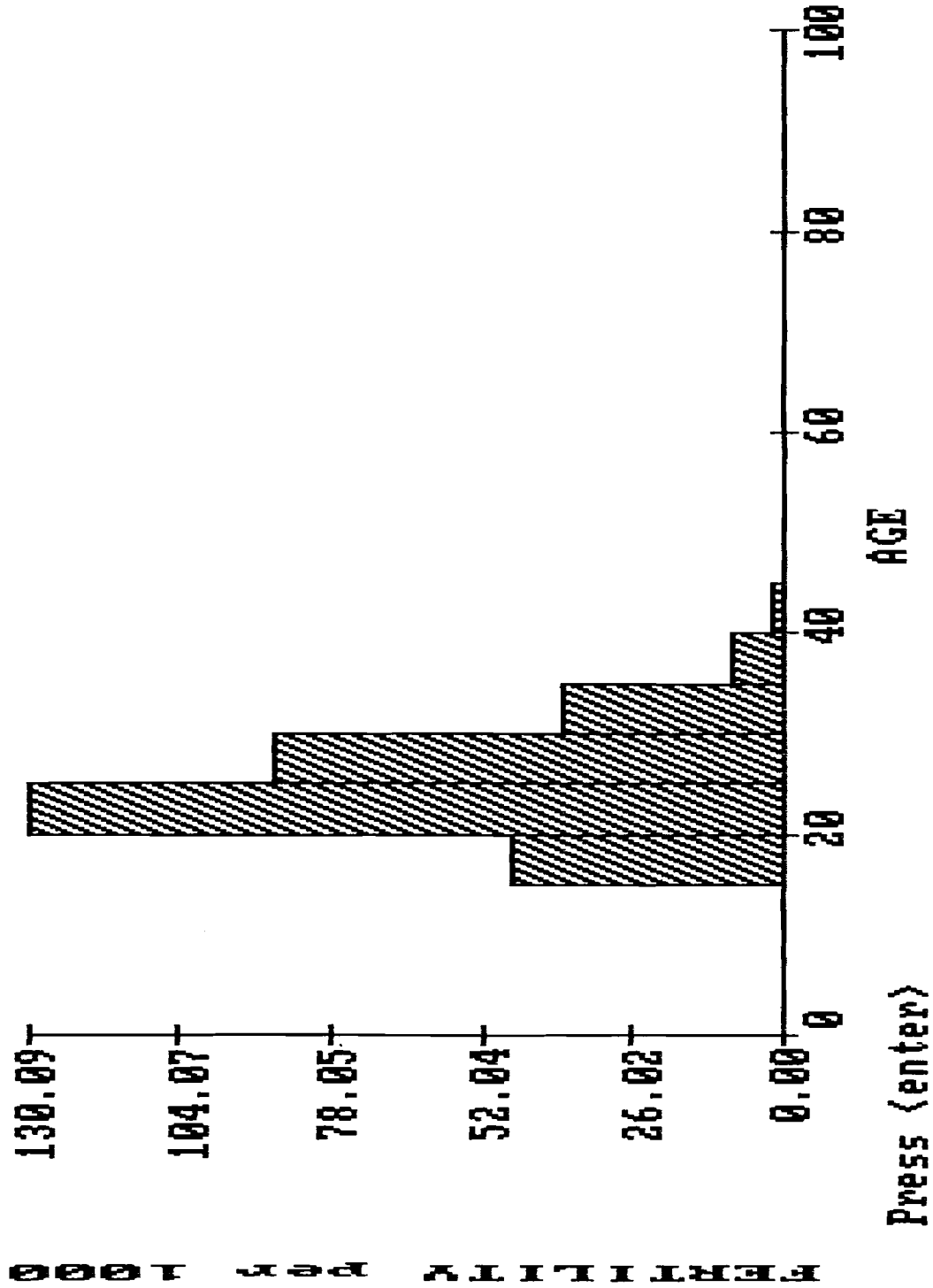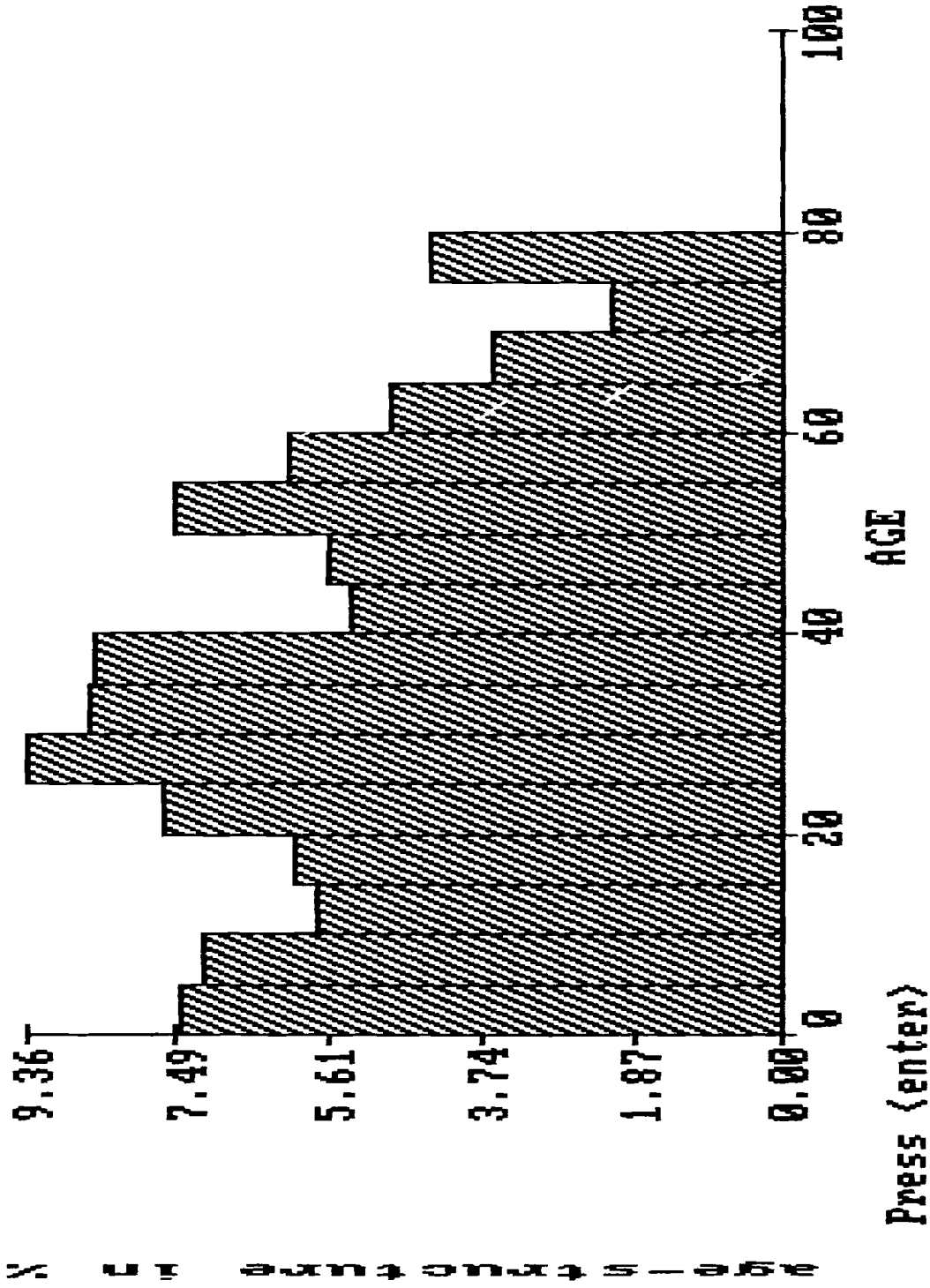
FEMALE, state-SOUTH

FERTILITY per 1000

130.09

104.07

78.05

52.04

26.02

0.00

0   20   40   60   80   100

AGE

Press <enter>

```
0 - exit
1 - population structure in %
2 - age-specific fertility per 1000
3 - age-specific mortality per 1000
enter number:1

enter sex:
1 - female, 2 - male, 3 -total
enter number:1




  0 - exit to previous level
  1 - NORTH
  2 - SOUTH
  3 - COUNTRY
--->1
```

FEMALE, state-NORTH

age-structure in %

AGE

Press <enter>

A.4. List of Variables for the Multistate Demographic Model

In the following, indices in brackets denote:

X — age,

I,J — number of states

IS — index of the sex (1 - female, 2 - male, 3 - total)

Population

POPR(X,I,IS) — population by age, state, and sex

PDTOT(X,IS) — population by age and sex

PTOTR(I,IS) — population by state and sex

PRCPDR(I,IS) — percent of population distribution by state and sex

POPTOT(IS) — total number of people in population and sex

Fertility

RATF(X,I) — fertility rate by age of mother and state

BIRTH(X,I) — number of newborn by age of mother and by state

BR(I,IS) — fertility rate by state and sex of newborn

B(I,IS) — number of newborn by state and sex

BRTOT(IS) — total fertility rate by sex of newborn

BTOT(IS) — total number of newborn by sex

GRR(I) — gross fertility rate by state

GRRN(I) — scenario gross fertility rate by state or a switch if < 0

Mortality

RATD(X,I,IS) — mortality rate by age, state, and sex

DR(I,IS) — mortality rate by state and sex

D(I,IS) — number of dead by state and sex

DRTOT(IS) — total mortality rate by sex

DEATH(X,I,IS) — number of dead by age, state, and sex

DTOT(IS) — total number of dead by sex

GDR(I,IS) — gross mortality rate by state and sex

GDRN(I,IS) — scenario gross mortality rate by state and sex or a switch if < 0

EXL(I,J,IS) — average time spent in state I for those who were born in state J by sex

EXLT(I,IS) — time that an arbitrary individual spent in state I by sex

Transitions between States

OMIG(X,I,J,IS) — number of transitions from state J to state I by age and sex

RATM(X,I,J,IS) — transition rate from state J to state I by age and sex

GMR(I,J,IS) — gross transition rate from J to I by sex

GMRN(I,J,IS) — scenario gross transition rate from J to I by sex or a switch if < 0

FMGR(I,IS) — number of transitions from J to I by sex

FMGRA(I,IS) — number of arrivals by state and sex

FMGRD(I,IS) — number of departures by state and sex

FMGRR(I,J,IS) — transition rate from state J to state I by sex

FMGRDR(I,IS) — rate of departures by state and sex

FMGRAR(I,IS) — rate of arrivals by state and sex

DFMGR(I,IS) — saldo of transitions by state and sex

FMGRT(IS) — total number of transitions by sex

Indices of Labor Force Participation

ACT(I,IS) — number of individuals of active age (from 15 to 64) by state and sex

RETM(I,IS) — number of elderly by state (65 years and over) and sex

CHLD(I,IS) — number of children up to 15 by state and sex

PASS(I,IS) — number of children up to 15 and elderly of 65 years and over by state and sex

ACTR(I,IS) — proportion of individuals of active age by state and sex

PRPA(I,IS) — dependency ratio $(\dfrac{\text{up to 15 and 65+}}{15-65})$ by state and sex

CHLDR(I,IS) — proportion of children by state and sex

RETMR(I,IS) — proportion of elderly by state and sex

ACTTOT(IS) — total number of individuals of active age by sex

CHLT(IS) — total number of children by sex

RETMT(IS) — total number of elderly by sex

PASST(IS) — total number of dependents by sex

ACTTR(IS) — proportion of individuals of active age by sex

CHLDTR(IS) — proportion of children by sex

RETMTR(IS) — proportion of elderly by sex

PRPTOT(IS) — dependency ratio by sex

Other Indices

AGEM(I,IS) — average age by state and sex

AGEMT(IS) — average age by sex

RNINC(I,IS) — natural growth rate by state and sex

RMINC(I,IS) — growth rate due to transitions by state and sex

RNINCT(IS) — total growth rate by sex

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