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## PROGRAM WORLD-DYN BASED ON FORRESTER MODEL OF WORLD DYNAMICS

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**Abstract:** Forrester model is a system of differential equations reflecting dynamics of 5 macro-economical variables (population, resources, etc.) . Such a model were developed more then 40 year ago and it proved to be an effective tool for qualitative analysis of world dynamics. By the moment there is no an accessible end-user program based on this model and our goal was the development of such a program with a comfortable graphical interface. In the paper we describe the program World-Dyn, which allows to set initial data and noise level, to set moments of parameter changes, to form the necessary visualization of results. We demonstrate the program functionality both on Forrester's example and on our example related with crisis.

**Keywords:** Forrester model, world dynamics, numerical analysis.

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### Introduction

At far 1970 year the Roman Club (a nongovernmental organization of politicians and scientists) asked John Forrester, a professor of MIT, to create a model, which could predict the further development of our world. After two weeks he presented his model "World-1", but this model proved to be too crude. Next year Forrester developed a new model called "World-2" and we consider this model in our paper [Forrester, 2003]

In his work Forrester pointed five main problems, which could provoke the possible future World Crisis. It is overpopulation of our planet, lack of basis resources, the critical level of pollution, food shortages and industrialization. He included five variables related with the mentioned problems:

- Population (P)
- Pollution (Z)
- Natural resources (R)
- Capital investment (fixed assets) (K)
- The proportion of funds invested in agriculture (X)

His work attracted many followers: Sergey Makhov [Machov,2003], Vladimir Egorov [Egorov, 1980] et al. Unfortunately, by the moment there is no an accessible end-user program based on Forrester model and our goal was the development of such a program with a comfortable graphical interface in the framework of MatLab package [Vasilyev, 2012]

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### Program description

#### 2.1 Forrester model and calculation scheme

Forrester's model is the system of 5 differential equation:

$$\frac{dP}{dt} = F_1(P, K, X, Z, R) \quad (1)$$

$$\frac{dK}{dt} = F_2(P, K, X, Z, R) \quad (2)$$

$$\frac{dX}{dt} = F_3(P, K, X, Z, R) \tag{3}$$

$$\frac{dZ}{dt} = F_4(P, K, X, Z, R) \tag{4}$$

$$\frac{dR}{dt} = F_5(P, K, X, Z, R) \tag{5}$$

Here  $F_i$  (i=1,2,3,4,5) are functions, which depend on the main variables. We used two methods for model calculation: Runge-Kutt method and Adams method [Petrov, 2006]. These methods are realized in MatLab (ode45 and ode113).

**2.2. Input/output of the main variables**

A user can get the results of classical Forrester model. For this he should open a set of menu:

“Options”-> “Counting settings”->Solve:

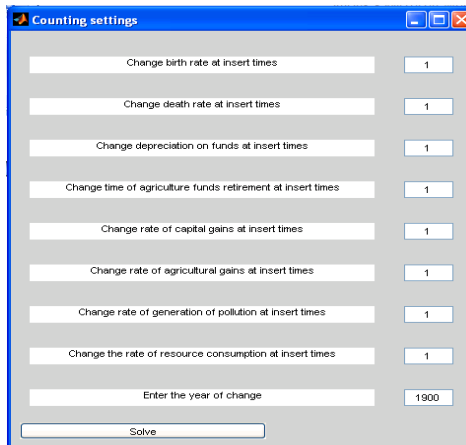


Fig.1. Model description

**2.3. Definition of noise in the initial data and on the stage of forecast**

A user can complete the experiments with noise. To make such an experiment in initial data the user should open “Options”-> “Noise settings (initial data)”.

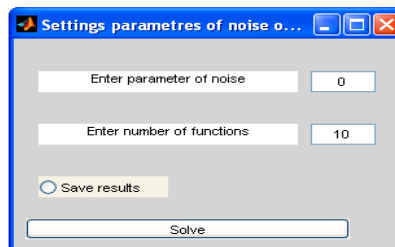


Fig.2. Menu for noise definition in the initial data

After that he chooses the noise level (parameter of noise) and the number of noise functions. To save the results the user points “Save results”. The forecast will be save as “change\_initial\_\*(name of variable)\_expectation\_\*(noise level)noise\_\*(the number of functions)functions\_\*(the percent of converge functions)%\_converge”. And finally the user enters “Solve”.

In order to complete the experiment with noise related with all variables on a forecast stage the user should open “Options”-> “Noise settings (forecast)”:

Fig. 3. Menu for noise definition on the forecast stage

After that he chooses the noise level (parameter of noise) and the number of noise functions. To save the results the user points “Save results”. The forecast will be saved as “change\_all\_\*(name of variable)\_expectation\_\*(noise level)noise\_\*(the number of functions)functions\_\*(the percent of converge functions)%\_converge”. And finally, the user should enter “Solve”.

In order to complete the experiment with noise related with one given variable on a forecast stage the user should open “Options”-> “Noise settings (only one function)”:

Fig. 4. Menu for noise definition on the forecast stage (one variable)

After that he chooses the noise level (parameter of noise), the number of noise functions, and the name of modifiable variable. To save the results the user points “Save results”. The expectation will be saved as “change\_only\_\*(name of modifiable variable) \_\*(name of variable)\_expectation\_\*(noise level)noise\_\*(the number of functions)functions\_\*(the percent of converge functions)%\_converge”. And, finally, he should enter “Solve”.

## 2.4. Messages of the program

When the program World-Dyn works it may inform the user:

- about process of modeling (Fig. 5)
- about final of calculation (Fig. 6)
- about errors (Fig.7 and Fig.8)

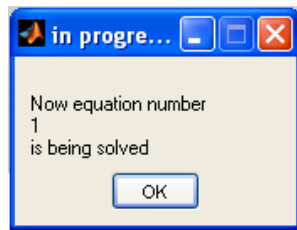


Fig. 5. Message about process of modeling

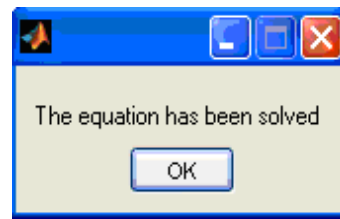


Fig.6. Message about final of calculation

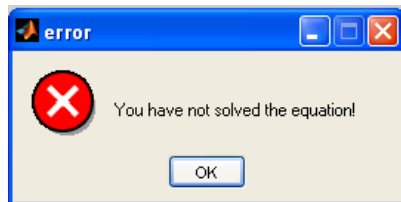


Fig.7. Message-1 about error

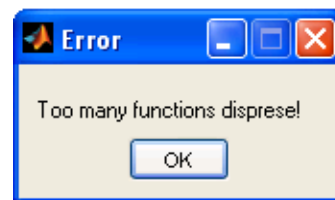


Fig.8. Message-2 about error

## Experiments

### 3.1 Classical Forrester example

The program WorldDyn was tested on the Forrester example and gave the correct results. For example, for the population we have:

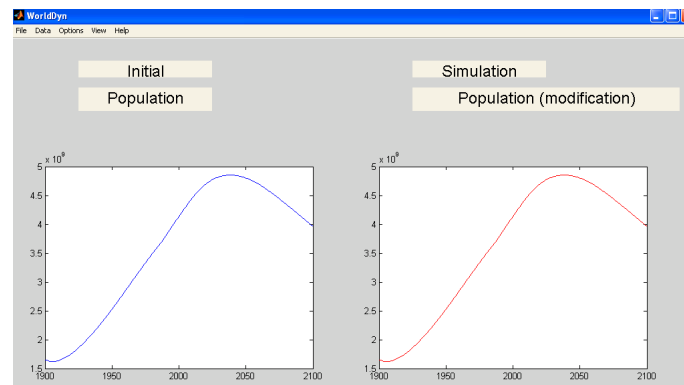


Fig.9. Classical Forrester model, calculation of population dynamics

With the noise we have (Fig.10):

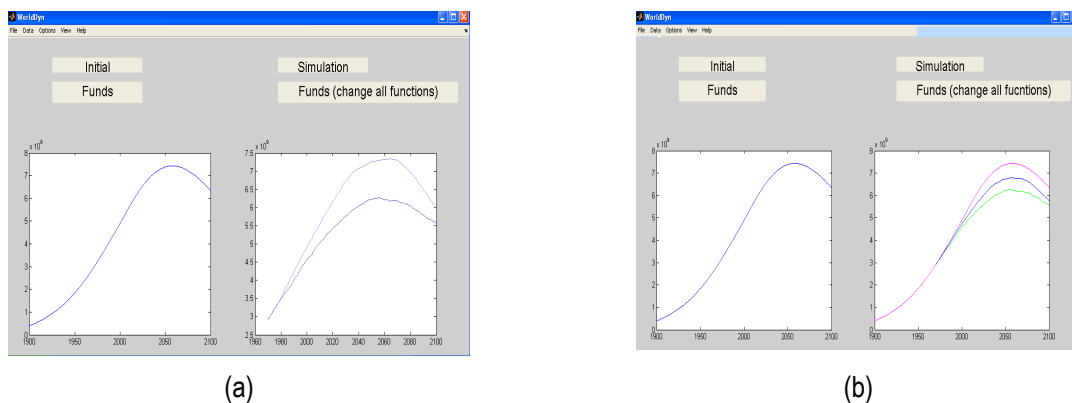


Fig. 10. Modeling with noise: (a) we display all noise functions; (b) we display initial function (magenta), expectation (blue) and the worst function (green).

### 3.2. Testing example

In our example, we change parameters of model: the birth rate decreases on 10% and the pollution decreases on 15% at 2012. We get the following results (Fig.11):

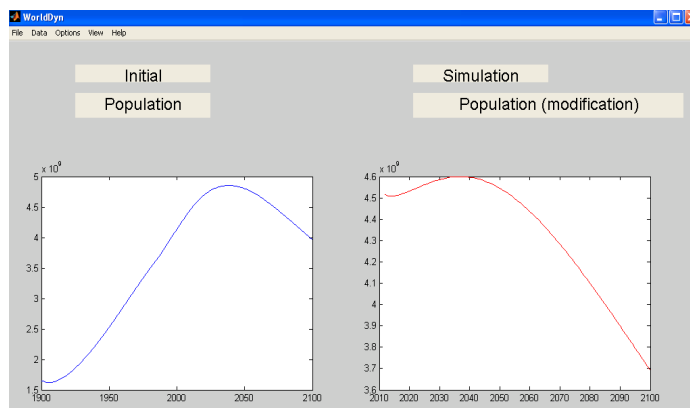


Fig.11. Abrupt change of the model parameters

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## Conclusion

In the paper we shortly described the program WorldDyn, which were developed in the MatLab shell. The program allows to model the world dynamics on the basis of Forrester model with noise. The program is supposed to be used by end-users which are not qualified in programming and mathematics

In the future this program will be transformed to the laboratory work for students of Russian Presidential Academy of national economy and public administration

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Major Fields of Scientific Research: mathematical modelling, world economy