FEI STU Bratislava Experience with Digital Story-Telling in Social Sciences Education

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Abstract: The paper deals with the new methods of teaching and self learning of system dynamics character of subjects of education and research with special focus to a class of social and economic sciences. Virtual 'story-telling' is a new method of explanation and electronic exposition of models of complex dynamical phenomena emerging in real economies based on combination of simulation methods, evolutionary animation and programmed learning. System dynamics approach using storytelling helps understanding a multitude of complex behaviours arisen in contemporary economy. Method is advantageous first of all in situations where explanation of complex phenomena is required too sophisticated mathematical tools. Using those simulation (numerical) tools is also beneficial as introductory phase before exact and/or explicit mathematical analysis of complex, system dynamic phenomenon. Evolutionary and system dynamical approach to using method of 'storytelling' helps students and other users in acquisition of better and more perpetual knowledge's about entities with system dynamic properties. Compared with storytelling based on PowerPoint that kind of virtual simulation based storytelling have a number of rewards among others but not least that those method are promoting of system dynamic reasoning, which guided participants in creative manner on path from mental modelling of reality in verbal terms to cybernetic modelling and via numerical simulation to building mathematical formalism of actual phenomena. The story building in appropriate software helps to improve architecture of knowledge's a creation of tacit and/or codified theories of a matter. The author illustrates using of that method on few examples selected from the class of economic sciences. ICT and experimentation in virtual laboratories may have a great impact on effectiveness, quality and perpetuality of knowledge acquisition in university level of education.

Keywords: ICT and artificial intelligence in education at university level, Virtual storytelling, evolution and system dynamics of story, models of evolving reality, advantages of experimentations in virtual laboratory and of conversion to virtual story, economic storytelling examples

1 Introduction – The Sense, Scope and Methods of Economic Storytelling

In education and research there are a large set of complex problems that is very pretentious for analysing them by traditional and easy methods. A lot of them they have system dynamic character and evolutionary nature. Several part of system dynamics is nonlinear. In such situations the problem solving needed sophisticated mathematical tools for achieving relevant results. Unfortunately not all student and researcher is able in any cases of problem solving use advanced mathematical and/or analytical tools with higher or at least satisfactory level of success.

The progress in ICT and advance in cybernetic and applied informatics helps in many cases solve such problems, at least in preliminary stages without perfect mathematical erudition. In this paper we deals with the new method of teaching and self learning of system dynamics character of subjects of education and research. Virtual 'story-telling' is a new method of explanation and electronic exposition of complex dynamical phenomena based on combination of simulation methods, evolutionary animation and programmed learning. Method is advantageous first of all in situations where explanation of complex phenomena is required too sophisticated mathematical tools. Using those simulation (numerical) tools is also beneficial as introductory phase before exact and/or explicit mathematical analysis of complex, system dynamic phenomenon.

Evolutionary and system dynamical approach to using method of 'storytelling' helps in acquisition of better and more perpetual knowledge's about entities with system dynamic properties. On virtual simulation based storytelling have a number of rewards among others but not least that those method are promoting of system dynamic reasoning, which guided participants in creative manner on path from mental modelling of reality in verbal terms to cybernetic modelling and via numerical simulation to building mathematical formalism of actual phenomena. The story building in appropriate software helps to improve architecture of knowledge's a creation of tacit and/or codified theories of a matter. The paper illustrates using of that method on few examples selected from the class of economic sciences.

We show that learning through simulation is the next dimension in quality improvement of research and education. Simulation modelling offers several distinct gains in learning opportunities beyond traditional quality improvement tools. A simulation model captures complex, multivariate system components and replicates system operation in compressed time. The visual aspect enables researchers and students to 'see' the effect of proposed changes and thus eliminates much of the fear of failure typically associated with change. Most important, simulation permits design of a total solution, addressing interactions of all system components.

In contemporary economies there are arisen multitude of system dynamic and evolutionary phenomena and complex behaviours of economic agents and institutions and organisations. System dynamics approach using virtual storytelling based on numerical simulations helps in analysing and in explanation for better understanding socio-economic evolution. Some of the most known complex behaviour is business cycle. Cyclical behaviour in developed economies emerged in 19th century was investigated by several economist in classic period of political economy and in modern economics too. One of very interesting reason determining emergence of cycles in economy is the contradiction among employer and employees. This problem is known as class struggle and was originated by Carl Marx. Richard Goodwin solved this task by analytical mathematical methods in system dynamics setup. Such approach requires high level of mathematical erudition and special skill. In this essay we suggest more direct approach based on numerical experimentation in PC. For this purpose we explicitly uses very effective software named STELLA developed in ISEE Systems Company.

2 Economic Problem Statement in Virtual Storytelling

Storytelling:

Passport to Success in the 21st Century

Why is there a resurgence of interest among today's business and organizational leaders in the ancient art of storytelling at a time when electronic communications might seem to make it obsolete? Human beings have been communicating with each other through storytelling since we lived in caves and sat around campfires exchanging tales. What is new today about the art of telling stories is the purposeful use of narrative to achieve a practical outcome with an individual, a community, or an organization. Four of the world's leading thinkers on knowledge management explore how storytelling will become the key ingredient to managing communications, education, training, and innovation in the 21st century.

Smithsonian Associates 2001

Virtual Story-telling is integral system approach combining verbal explanation of problem with cybernetic modelling, numerical simulation, programmed learning and mathematic analysis. In first sight is similar with PowerPoint animation, but they have several innovations and is equipped by abundance of useful tools. In Fig. 1 we can see the window of programmed storytelling steps. In Fig. 2 there is open the desk to write the verbal text of a story. The next picture show one of the finished info box used in story – Fig. 3. In Fig. 4 there is showed of Phillips curve in story panel as a picture of STELLA graph. The part of mathematical forms (in discrete time) we can see in Fig. 5, and in Fig. 6 there is a part of cybernetic scheme (block diagram) of Goodwin model in STELLA.

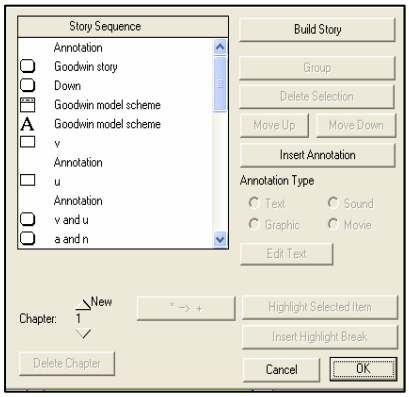


Figure 1
The programmed story-telling: Working window with Story sequence

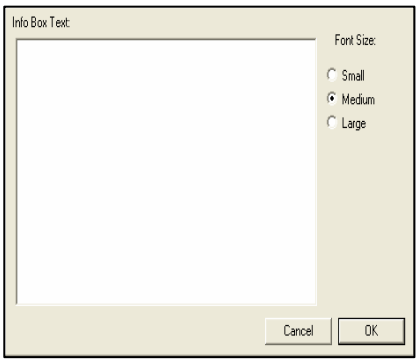


Figure 2
Signboard for info text writing

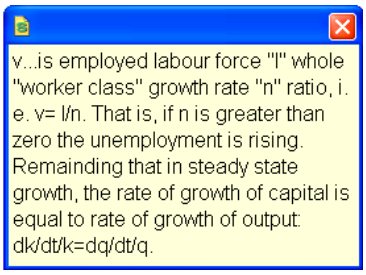


Figure 3
Info box opening in a story panel

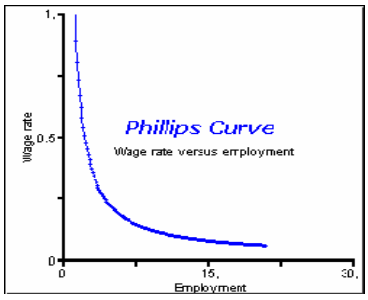


Figure 4
Showing the graph in story panel

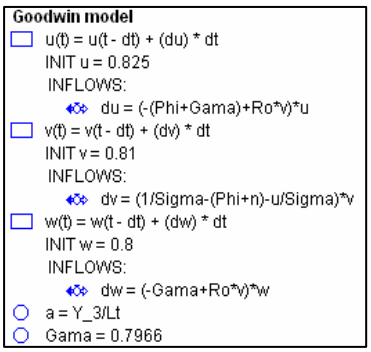


Figure 5
Exhibition of Math formulae of Goodwin model in a STELLA fashion

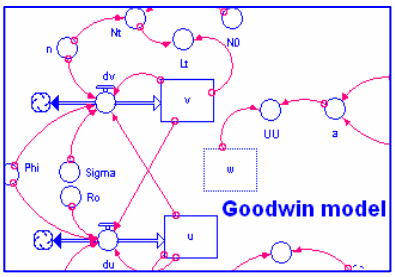


Figure 6
The cutout from a cybernetic block diagram of model in STELLA

After these few illustration we are going to shed light on some mathematical difficulties of Goodwin model of cyclical behaviour of classic economic system ('difficulties' naturally only from the point of view of first semester students). In this association somebody may ask the question: 'Is Goodwin's analytical model of class struggle really difficult for undergraduate student?' The answer may be positive. For illustration of the fact that mathematics for analysis of cyclical behaviour in complex economic systems is really very sophisticated matter for beginners, we exhibit here a brief analytical description of struggle of workers for higher wage (we used only some of most difficult formulae for beginners).

Cutout from mathematical explanation of Goodwin model of cyclical behaviour:

$$d\mu/dt = [1/v - (\theta + n) - u/v]\mu \qquad (6a)$$

$$du/dt = [-(\alpha + \theta) + \beta\mu]u \qquad (6b)$$

It is obvious that which trajectory dominates will depend on initial conditions as well as the structure of the equations. To get at the resulting dynamic, let us set up the differential equations as a ratio to eliminate *dt:*

$$d\mu/du = [d\mu/dt]/[du/dt] = [1/v - (\theta + n) - u/v]\mu/[-(\alpha + \theta) + \beta\mu]u \qquad (7a)$$

so:

$$d\mu\,[-(\alpha + \theta) + \beta\mu]u = du[1/v - (\theta + n) - u/v]\mu \qquad (7b)$$

or factoring out μ from the left and u from the right:

$$d\mu[-(\alpha + \theta)/\mu + \beta]\mu u = du[1/vu - (\theta + n)/u - 1/v]\mu u \qquad (7c)$$

so dividing through by μu:

$$d\mu[-(\alpha + \theta)/\mu + \beta] = du[1/vu - (\theta + n)/u - 1/v] \qquad (7d)$$

integrating both sides:

$$\int[-(\alpha + \theta)/\mu + \beta]\, d\mu = \int[1/vu - (\theta + n)/u - 1/v]\, du \qquad (7e)$$

which yields:

$$-(\alpha + \theta)\ln\mu + \beta\mu = [1/v - (\theta + n)]\ln u - u/v + c \qquad (7f)$$

where c is a combined constant of integration. Introducing dummy variable z, then the left side can be written:

$$z = F(\mu) = -(\alpha + \theta)\ln\mu + \beta\mu$$

and for the right hand side:

$$z = G(u, c) = [1/v - (\theta + n)]\ln u - u/v + c$$

End of cutout.

3 Similarities between Goodwin's and Ecological Lotkas-Volterras Models

Among severity of possible examples of complex cyclical behaviours there is an exhibition of cyclical behaviour as some virtual happening of similarities between Lotka-Volterra model of predator-prey and class struggle model in terms of simulation model in software STELLA:

In formal and/or mathematical logic the 'ecological relation' between predator versus prey (Lotka-Volterra model) and capitalist versus workers (Goodwin model) is so to speak identical. Apart from continues model of business cycle like Goodwin mathematical treatment, STELLA works in discrete time. In Fig. 10 there is predator-prey model with diagram of results and in Fig. 6 (in page № 4) is capitalist-workers (Goodwin) model, both in STELLA setup.

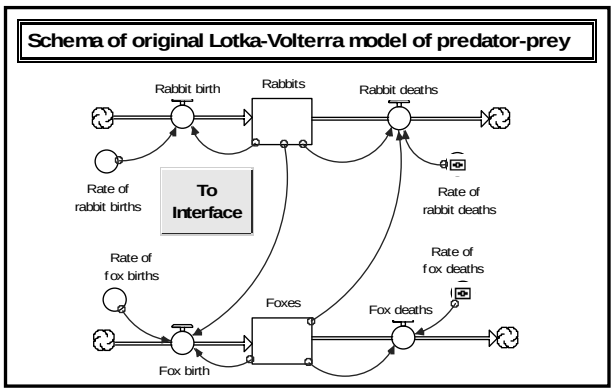


Figure 7
The cybernetic block diagram of ecological predator-prey model in STELLA

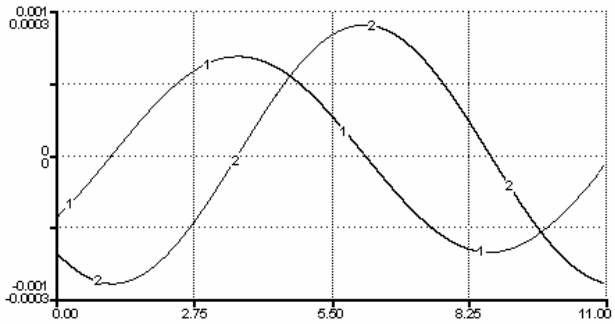


Figure 8
Oscillation between rabbits and foxes populations in STELLA laboratory

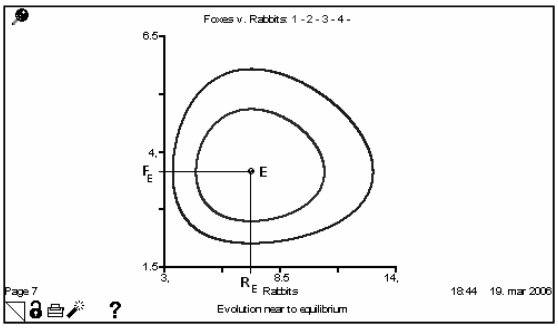
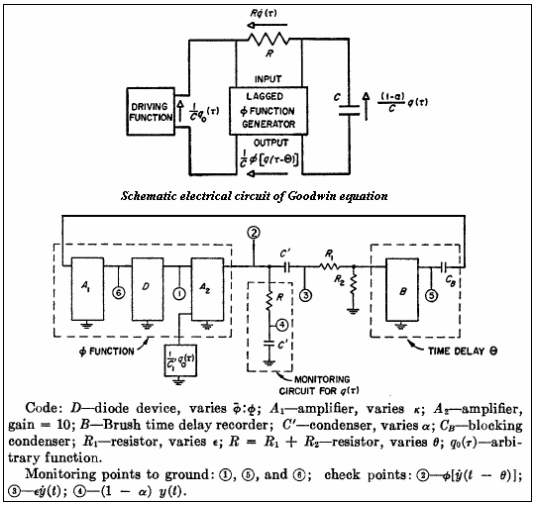


Figure 9
The cybernetic block diagram of ecological predator-prey model in STELLA

Naturally the students in electrical engineering and information technology faculties can find a lot of similarities with those process. The students of automatic control can find similarities with the problem of controlling two coupled pendulums. Other simularity may be find in electrical circuits as we can see in the subsequent schema (see Fig. 10).



Code: D—diode device, varies $\bar{\varphi}:\phi$; A_1—amplifier, varies κ; A_2—amplifier, gain = 10; B—Brush time delay recorder; C'—condenser, varies α; C_B—blocking condenser; R_1—resistor, varies ϵ; $R = R_1 + R_2$—resistor, varies θ; $q_0(\tau)$—arbitrary function.

Monitoring points to ground: ①, ⑤, and ⑥; check points: ②—$\phi[\dot{y}(t - \theta)]$; ③—$\epsilon\dot{y}(t)$; ④—$(1 - \alpha)\ y(t)$.

Figure 10
The modification of Goodwin model in electrical circuit fashion

4 Converting Models of Economic Behaviour to form of Storytelling in Virtual Environment

The final stage of exhibition cyclical behaviour is a virtual story telling in integral terms (verbal mental model plus mathematical model plus simulation model with experimentation plus showing results of experiments in graphical, diagrammatic and table form plus identification of experimental results with objective reality):

The creator and designer of storytelling method in STELLA was Barry Richmond. He has developed several interesting stories in software STELLA first of all as examples for introducing possibilities of using STELLA for diffusion of virtual storytelling methods among teachers and students and/or any other users. We are using STELLA in our department for more than ten years. As one of several examples we show relatively simple story on electricity cost in a firm caused by price fluctuation.

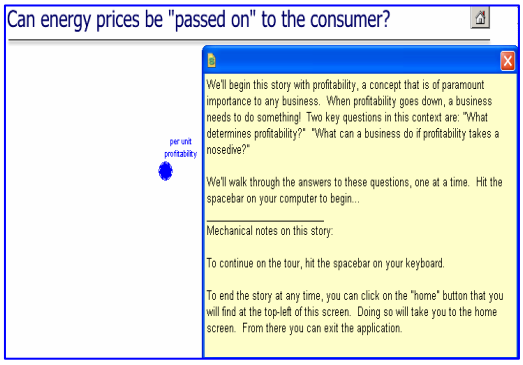


Figure 11
Title page of a story in Interface of STELLA and first step of energy price story

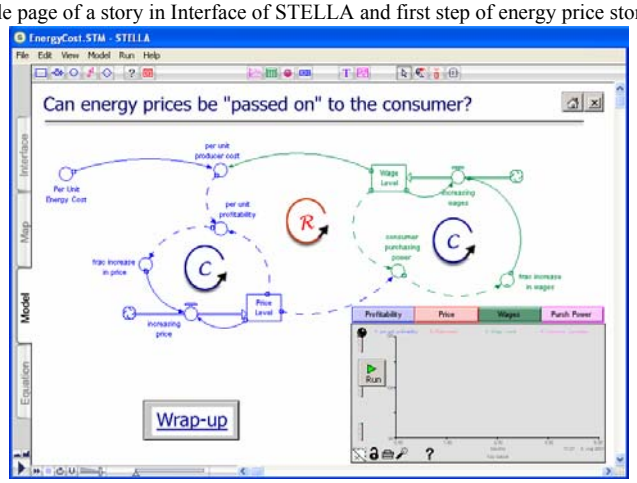


Figure 12
STELLA working board named "Model"

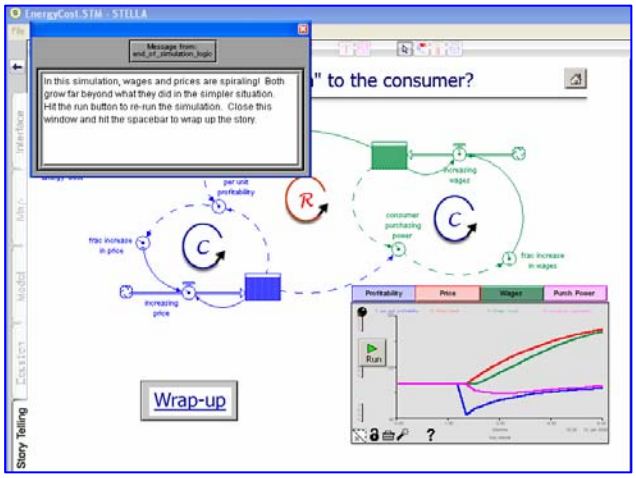


Figure 13
Situation in STELLA after simulation running

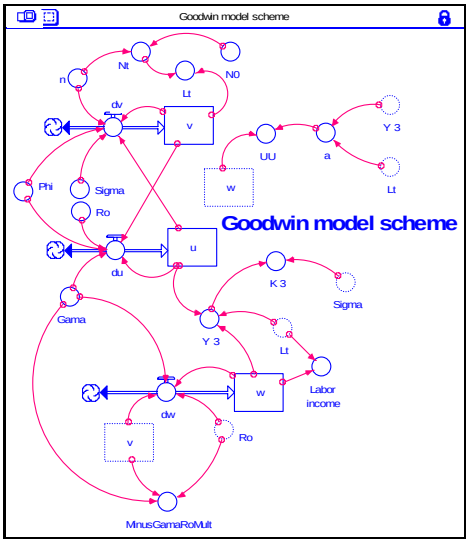


Figure 14
Whole Goodwin model scheme in STELLA

System dynamics approach helps understanding a multitude of complex behaviours arisen in contemporary economy. Some of most known complex behaviour is business cycle. Cyclical behaviour emerged in 19th century was investigated by several economist like Marx, Marshall, Kondratjev, Schumpeter, Kalecki, Kaldor, Harrod and Goodwin among others. One of very interesting reason determining emergence of cycles in economy is the contradiction among capitalists and workers. This problem is known as class struggle and was originated by Carl Marx. Richard Goodwin solved this task by analytical mathematical methods in system dynamics setup. Such approach requires high level of mathematical erudition and special skill. The author in this essay suggests more direct approach based on numerical experimentation in PC. For this purpose he explicitly uses software STELLA developed in ISEE Systems Company.

Figure 15
Information box setting in STELLA Interface board

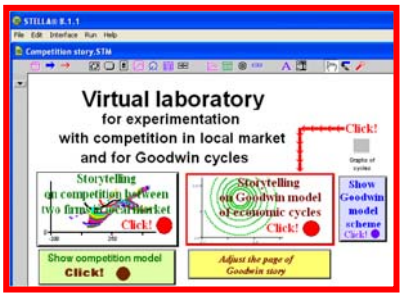
5 Cut-Out from Own Story on Goodwin Theory in STELLA Software

Looking on Introductory panel in STELLA Interface:

Before beginning the storytelling you have to push the button *Adjust* the page of Goodwin story!

First Label after clicking button on

Interface ►►►



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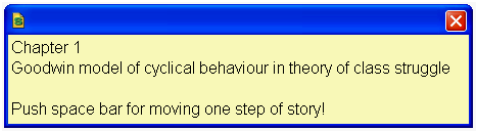
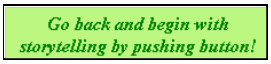
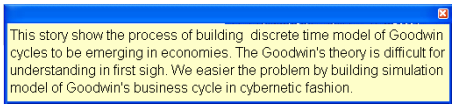


After adjusting the Goodwin story page you have to push the button:

Second step (first pushing the space bar):



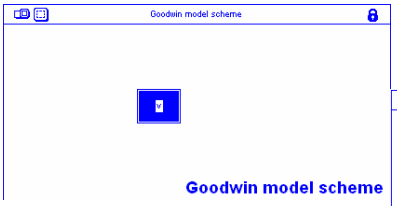
Third step (second pushing the space bar) – the basic verbal feature of Goodwin's model:



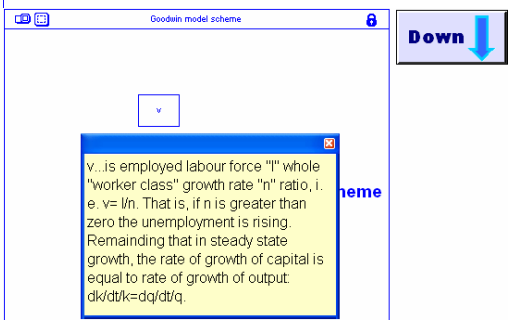
Fourth step: Button as 'Knob operation' is emerged. Pushing this button we are jumping to required place in 'Down' direction.

The basic verbal features of Goodwin's model looks as following simply story: - 1.high employment generates wage inflation which can - 2. increase the wage share of workers in output; but this will, in turn, - 3. reduce the profits of capitalists and thus reduce future investment and output, that reduction in output will in turn - 4. reduce demand for labour force, i. e. for employment and consequently lead to - 5. lower wage inflation or even deflation and thus reduce the wage share of workers, but as workers wage share declines, then – 6. profits increases and, parallel with them lead, to rise of investment, higher investment will – 7. lead to higher employment and thus improve the bargaining power of workers and consequently lead to the wages growth. It is clear immediately that such process must be cyclical. For better portraying the process Goodwin adds supplementary exogenous growth components - namely, labour force supply growth and productivity growth.

X+1 step:

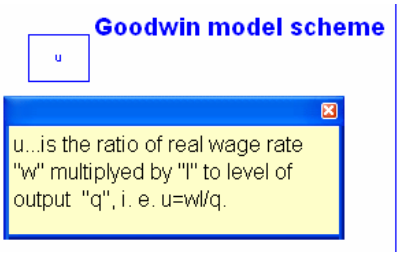


X+2 steps:



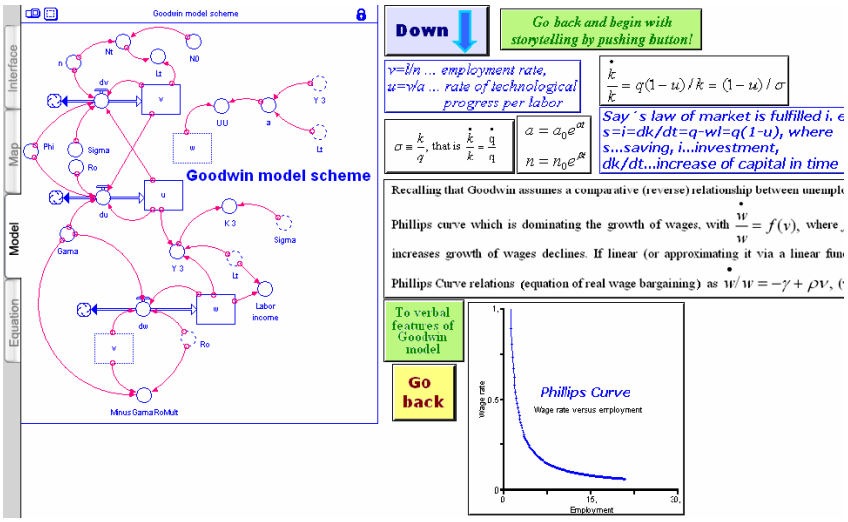
X+3 steps:

X+4 steps:

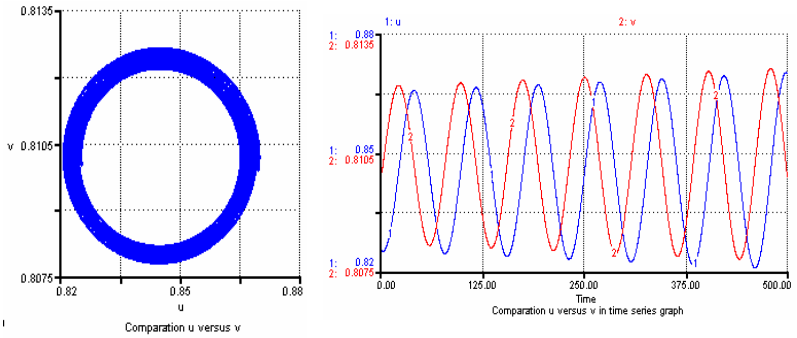


…and so on…

This is a partial snapshot from STELLA Goodwin's story after a greater number of steps:



These are two snapshots of simulation result in graph:



Conclusions

Because of bounded extent of paper there was exhibited only a few of possible causes of telling economic stories in virtual environment. There was introduced some of the most known complex economic behaviour – such as – business cycle. Cyclical behaviour emerged in 19th century was investigated by several economist like Marx, Marshall, Goodwin among others. One of very interesting reason determining emergence of cycles in economy is the contradiction among capitalists and workers. This problem is known as class struggle and was originated by Carl Marx. Richard Goodwin solved this task by analytical mathematical methods in system dynamics setup. Such approach requires high level of mathematical erudition and special skill. In this paper was suggested and in brief format was introduced more direct approach based on numerical

experimentation in PC. In that base the other contribution is telling story on cyclical behaviour in economic systems in virtual environment, namely in virtual laboratory constructed in a software STELLA. For this purpose was explicitly used software STELLA developed in ISEE Systems Company. This approach is a promising start to easier, better and lasting valued (forced in perpetuality) economic knowledge. Naturally such mode of digital story-telling one can benificially use for a lot of others complex subjects.

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