UDC 004.94

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INVESTIGATION OF PARAMETERS OF THE SIMULATION MODELS OF DYNAMIC SYSTEMS WITH CHANGEABLE ON STATE DELAY

Annotation. This paper studies the influence of parameters of nonlinear dynamic systems with delay. We have built simulation of dynamic systems. Also we obtained phase portraits and graphics of the dynamic system behavior.

Keywords: dynamic system, nonlinear delay time, simulation model.

Introduction

Many of the processes that accompany a person in everyday life characterized by delays in time. The delay may have a different origin nature: inertia of some elements of the system, limiting the flow process or chemical process, and so on. Preferably, the researchers simulate these processes with the use of differential without delay in time, because they believe the impact of this delay zero or negligible, so consider a system under ideal conditions. However, ignoring the delay can have a significant impact on the behavior of high-quality models and in some cases lead to significant differences in the results of experiments.

This paper examines the impact of dynamic system parameters for its qualitative behavior.

Statement of the problem

The purpose of this research is to study dependence of nonlinear dynamic systems behavior with a delay of time settings provided varying delay. This study was conducted by simulation solutions of dynamical systems using a simulation model constructed in software for building simulation models Anylogic Free Release.

Investigation of simulation model

Using the methodology of system dynamics analyst can understand the effects that may arise from external influence and change system settings. This allows you to compare alternative solutions and choose the best, which is the main task analysis. We perform analysis considered the problem of determining the balance point in the phase plane and the motion in the neighborhood of balance point.

To study the phase portrait of dynamical systems is necessary to analyze the behavior of solutions with different sets of model parameters to see which attractors coincide with received trajectory.

Consider in more details some systems. We studied dynamical systems described by nonlinear differential equations with delay. The following laws were considered delay changes: $\tau(t)=\gamma\cdot\sqrt{t+0,01}$ and $\tau(t)=\gamma\cdot t$, with parameter γ, and also – $\tau(t)=e^{0,01\cdot t}$.

The first system is described by the following equation

$$\begin{cases} x'(t)=b-K\cdot x\big(t-\tau(t)\big), & t>0, \\ x(t)=\varphi(t), & t\le 0, \end{cases} \tag{1}$$

where b and K are set numerical parameters of the system, and $\tau(t)$ is a nonlinear delay. General view of the created simulation model is shown in Figure 1.

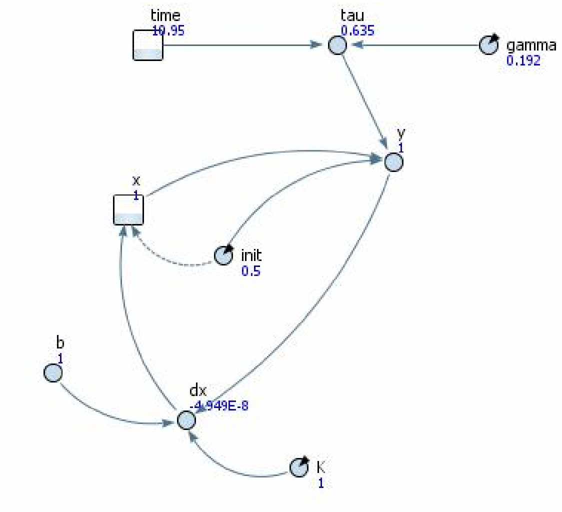
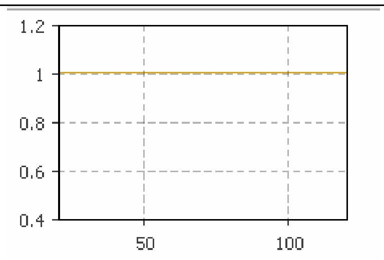
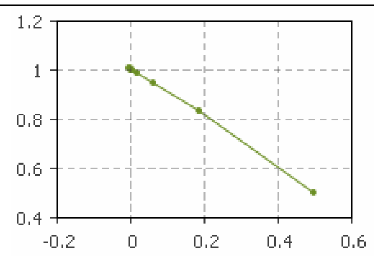


Figure 1 - Simulation model of dynamic system (1)

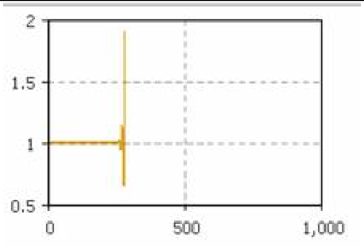
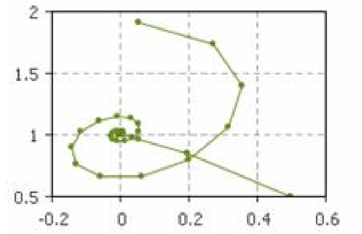
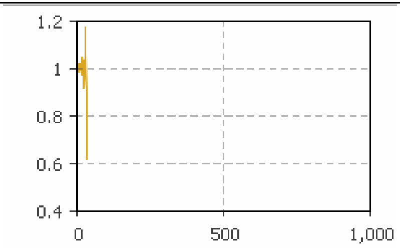
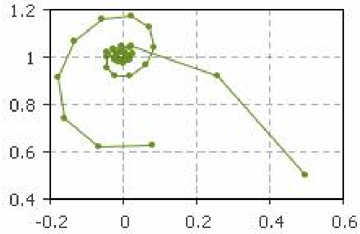
Below is a table showing the behavior of the dynamic system (1) and its phase portrait for some values of parameters γ and K. In this case parameter $b=1$ was fixed, initial condition – $x(t)=0,5$ for $t\le 0$.

1. $\tau(t)=\gamma\cdot\sqrt{t+0,01}$ and $K=1$.

Table 1 - Test results of the first simulation model

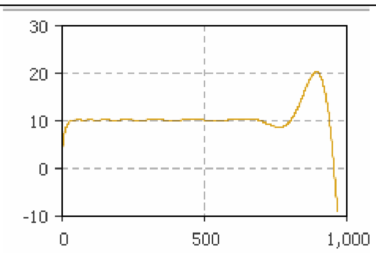
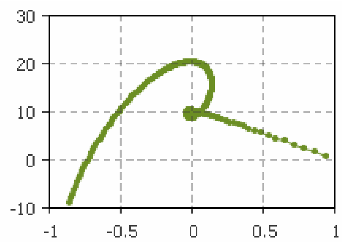
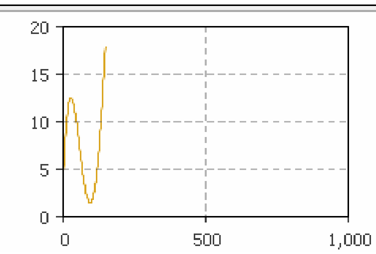
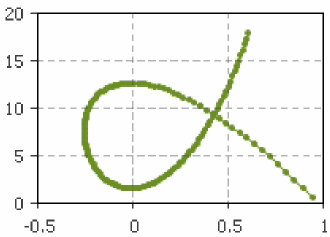
Value of γ	Dependence $x(t)$	Phase portrait
$\gamma=0,1$		

Continued Table 1

$\gamma = 0,2$		
$\gamma = 0,5$		

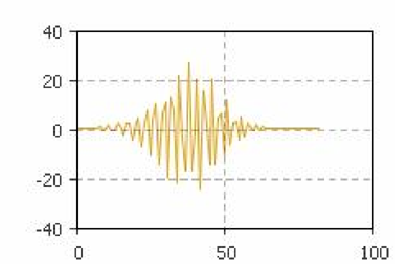
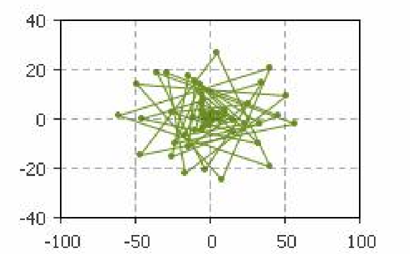
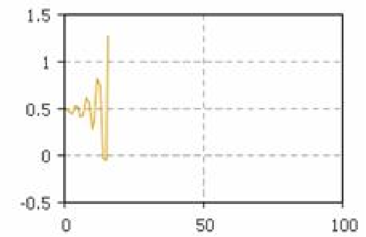
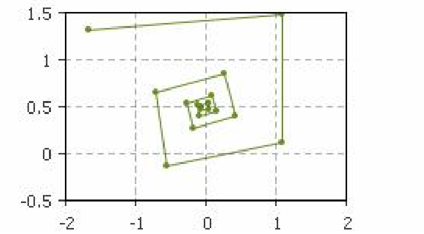
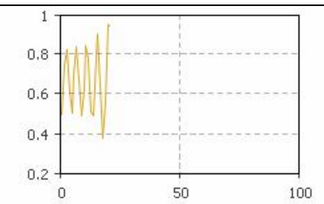
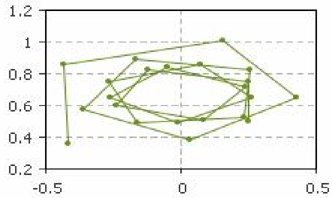
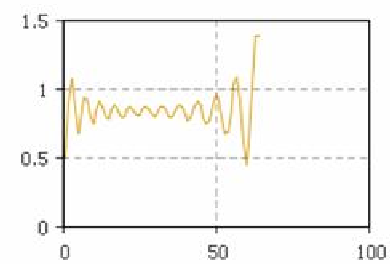
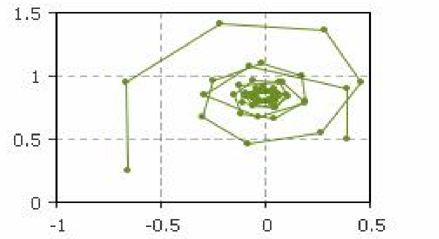
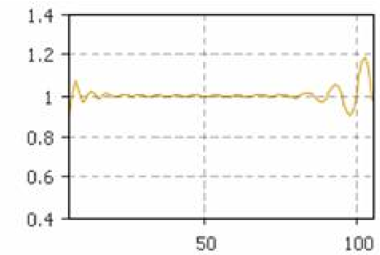
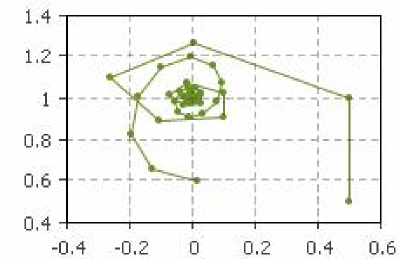
2. $\tau(t) = \gamma \cdot t$ and $K = 1$.

Table 2 - Test results of the first simulation model

Value of γ	Dependence $x(t)$	Phase portrait
$\gamma = 0,1$		
$\gamma = 0,5$		

3. $\tau(t) = e^{0,01 \cdot t}$, $b = 1$ and $x(t) = 0,5$ for $t \leq 0$.

Table 3 - Test results of the first simulation model

Value of K	Dependence $x(t)$	Phase portrait
$K = 2,3$		
$K = 2,1$		
$K = 1,5$		
$K = 1,2$		
$K = 1$		

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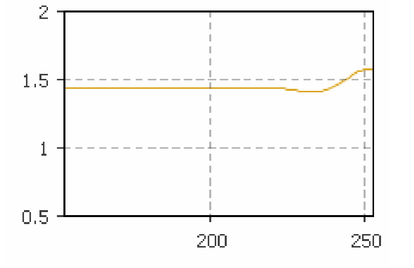
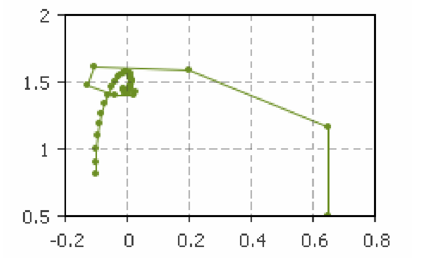
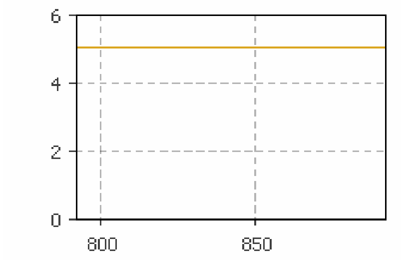
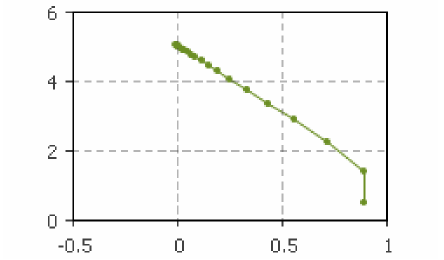
Continued Table 3

$K = 0,7$		
$K = 0,2$		

As a second example, consider a system differential equations with a delay

$$\dot{x}(t) = \beta u(t) - \alpha x(t-\tau), t > t_0,$$

$$x(\tau) = \phi_0(\tau) \;\; npu, \;\; t_0 - \tau \le \tau \le t_0 \qquad (2)$$

where $u(t) = 2\cos(0.3t)$ – state of the system in time moment *t*, β and α are set numerical parameters of the system, and $\tau(t)$ is a delay. General view of the created simulation model is shown in Figure 2.

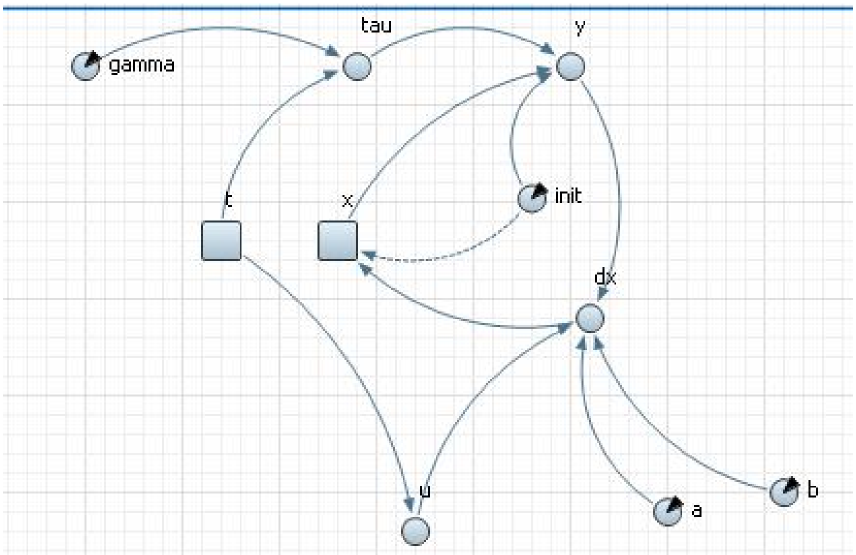
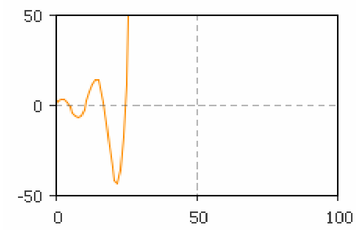
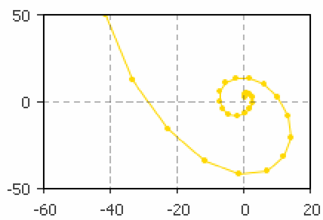
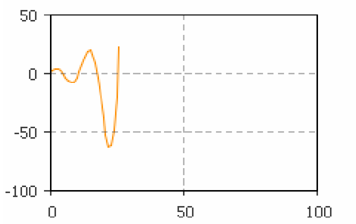
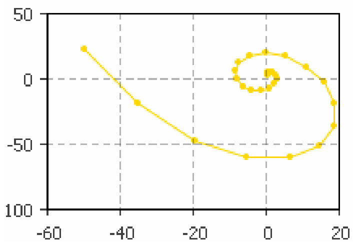
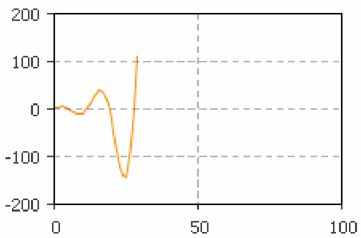
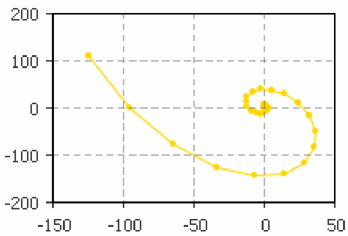


Figure 2 - Simulation model of dynamic system (2)

Below is a table showing the behavior of the dynamic system (2) and its phase portrait for some values of parameters γ and K. In this case parameter $\beta = 1$ was fixed, initial condition $x(t) = 0,5$ for $t \le 0$.

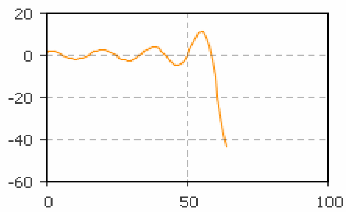
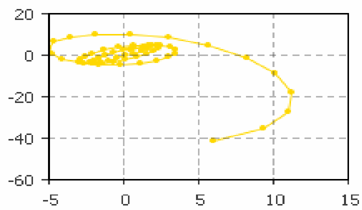
1. $\tau(t) = \gamma \cdot \sqrt{t + 0,01}$ and $\alpha = 1$.

Table 4 - Test results of the second simulation model

Value of γ	Dependence $x(t)$	Phase portrait
$\gamma = 0,1$		
$\gamma = 0,2$		
$\gamma = 0,5$		

2. $\tau(t) = \gamma \cdot t$ and $\alpha = 1$.

Table 5 - Test results of the second simulation model

Value of γ	Dependence $x(t)$	Phase portrait
$\gamma = 0,1$		

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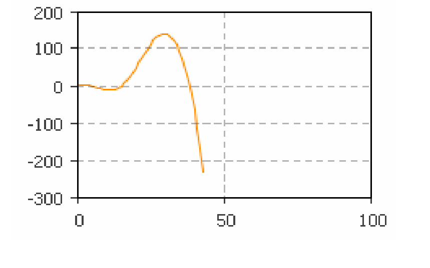
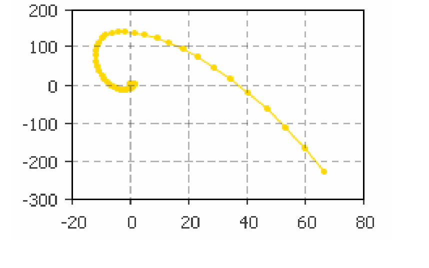
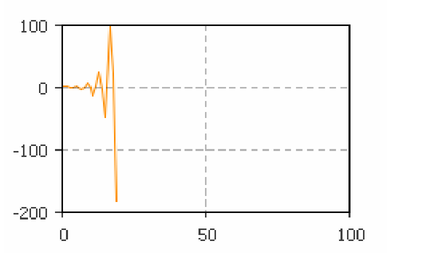
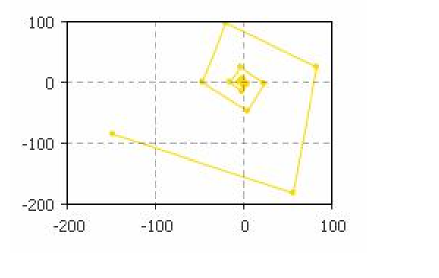
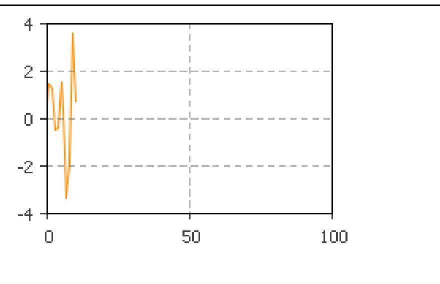
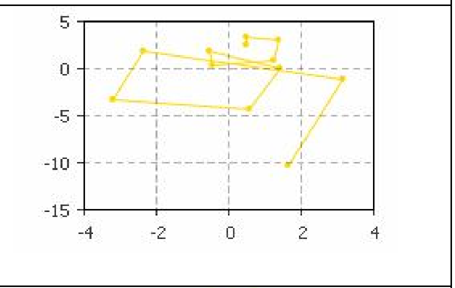
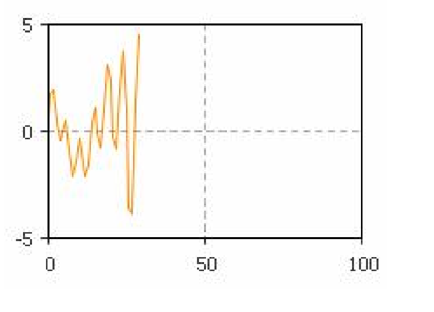
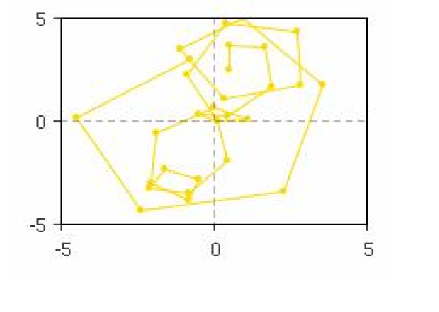
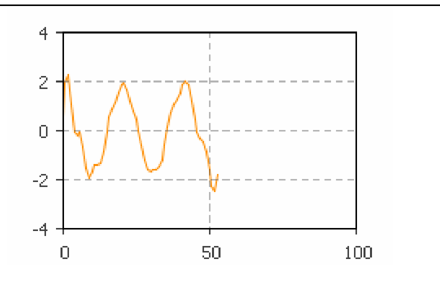
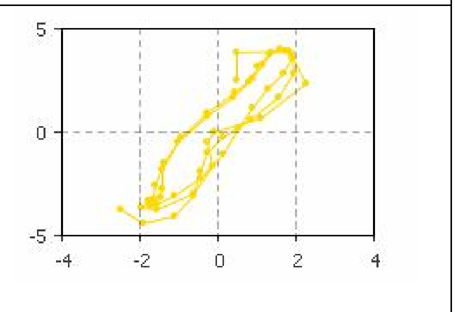
Continued Table 5

$\gamma = 0,5$		

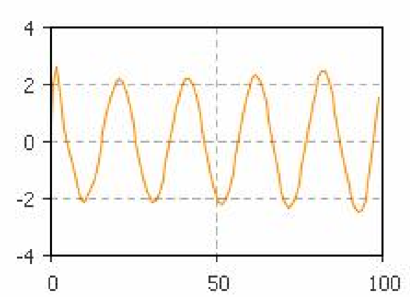
3. $\tau(t) = e^{0,01 \cdot t}$ for $t \le 0$.

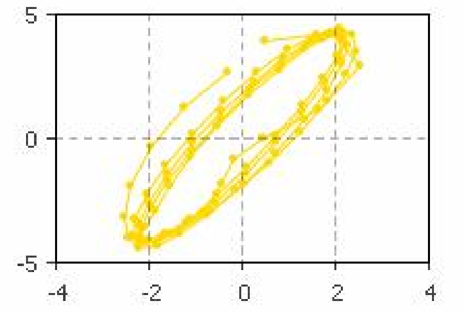
Table 6 - Test results of the second simulation model

Value of K	Dependence $x(t)$	Phase portrait
$\alpha = 2.3$		
$\alpha = 2.1$		
$\alpha = 1.5$		
$\alpha = 1.2$		

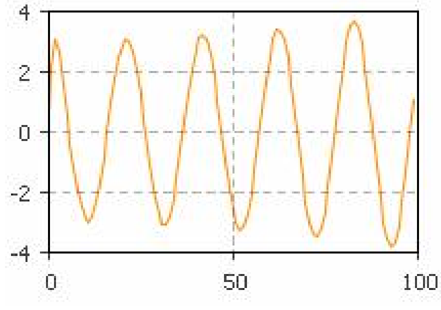
Continued Table 6

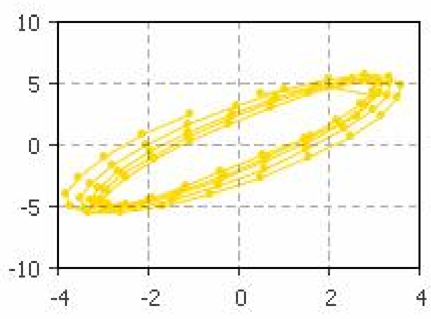
$\alpha = 1$



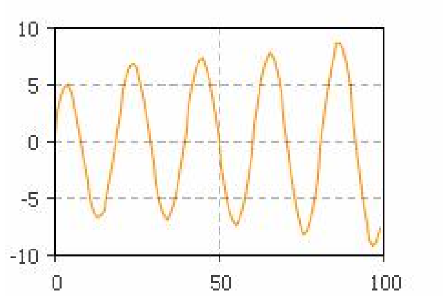


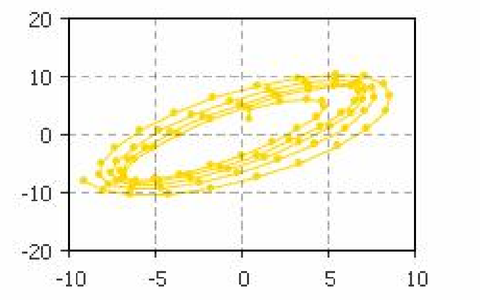
$\alpha = 0.7$





$\alpha = 0.2$





Conclusions

In this work the behavior of the dynamic system with 3 types delay: a power, linear and exponential. If the solution to the exponent delay dynamic system changes its qualitative behavior depending on the ratio of convergence to a fixed value to the oscillations of infinitely increasing amplitude. In late exponential dynamic system solution comes in constant operation since the point at which the value of delay $\tau(t)$ becomes equal with time t. In case of linear delay $\tau(t) = \gamma t$ solution of systems (1) and (2) diverges.

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Бабенко Ю.В., Ланская С.С. Исследование параметров имитационной модели динамической системы с изменяющимся по состоянию запаздыванием / Ю.В. Бабенко, С.С. Ланская // Системные технологии. Региональный межвузовский сборник научных трудов. – Выпуск ??(??). – Днепр, 2017. – С. ??–??.

В работе проводится исследование влияния параметров динамической системы с нелинейным запаздыванием. Построена имитационная модель динамической системы. Получены фазовые портреты и графики поведения решения динамической системы.

Библ.3, ил. 1,

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Бабенко Ю.В., Ланська С.С. Дослідження параметрів імітаційної моделі динамічної системи зі змінним за станом запізненням / Ю.В. Бабенко, С.С. Ланська // Системні технології. Регіональна міжвузівська збірка наукових праць. – Випуск ??(??). – Дніпро, 2017. – С. ??–??.

В роботі проводиться дослідження впливу параметрів динамічної системи з нелінійним запізненням. Побудовано імітаційну модель динамічної системи. Отримано фазові портрети та графіки поведінки розв’язку динамічної системи.

Бібл. 3, іл. 1.

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Babenko Yu., Lanskaya S. Investigation of parameters of the simulation models of dynamic systems with changeable on state delay / Yu. Babenko, S. Lanskaya // System technologies. Regional interuniversity compendium of scientific works. – Vol ? (?). – Dnipro, 2017. – Pp. ? –?.

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