

Лабораторная работа №5

Математическая модель «хищник-жертва» (модель Лотки-Вольтерры)

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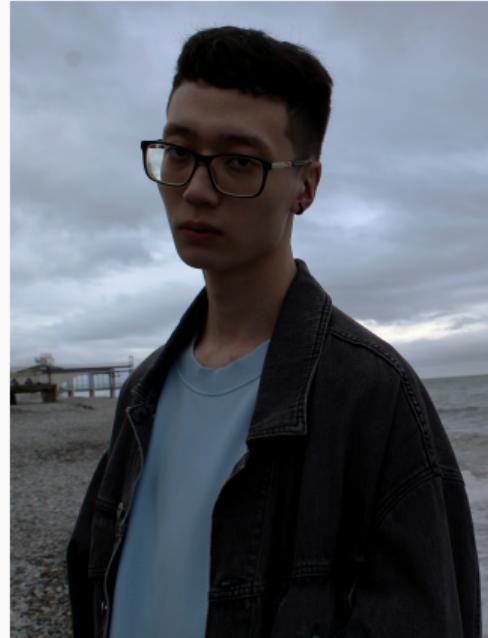
07 марта 2023

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Информация

Докладчик

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Вводная часть

Актуальность

- Необходимость навыков моделирования реальных математических задач, построение графиков.

Объект и предмет исследования

- Язык программирования Julia
- Язык моделирования Modelica
- Математическая модель «хищник-жертва» (модель Лотки-Вольтерры)

Цели и задачи

- Продолжить знакомство с функционалом языков Julia и Modelica.
- Создать математическую модель Лотки-Вольтерры с помощью данных языков.
- Построить графики состояния систем в соответствии с поставленными задачами.

Материалы и методы

- Языки:
 - язык программирования Julia
 - язык моделирования Modelica
- Дополнительный комплекс программ:
 - Программное обеспечение OpenModelica
 - Интерактивный блокнот Pluto.jl

Процесс выполнения работы

Формулировка задания

Формулировка задания

Для модели «хищник-жертва»:

$$\begin{cases} \frac{dx}{dt} = -0.16x(t) + 0.045x(t)y(t) \\ \frac{dy}{dt} = 0.36y(t) - 0.033x(t)y(t) \end{cases}$$

Построить график зависимости численности хищников от численности жертв, а также графики изменения численности хищников и численности жертв при следующих начальных условиях: $x_0 = 10$, $y_0 = 15$. Найти стационарное состояние системы.

Pluto.jl

Код задания №1

```
begin
    import Pkg
    Pkg.activate() ⚡
    using DifferentialEquations
    using LaTeXStrings
    import Plots
end
```

Activating project at `~/.julia/environments/v1.8`

T

Период времени

```
begin
    const c = 0.16
    const d = 0.045
    const a = 0.36
    const b = 0.033
    const x0 = 10
    const y0 = 15

    "Начальные условия: u0[1] -- x0, u0[2] -- y0"
    u0 = [x0, y0]

    "Период времени"
    T = (0.0, 70.0)
end
```

F!

Правая часть нашей системы, p, t не используются. u[1] – x, u[2] – y

```
"Правая часть нашей системы, p, t не используются. u[1] -- x, u[2] -- y"
function F!(du, u, p, t)
    du[1] = -c * u[1] + d * u[1] * u[2]
    du[2] = a * u[2] - b * u[1] * u[2]
end
```

```
prob = ODEProblem with uType Vector{Int64} and tType Float64. In-place: true
  timespan: (0.0, 70.0)
  u0: 2-element Vector{Int64}:
    10
    15
prob = ODEProblem(F!, u0, T)
```

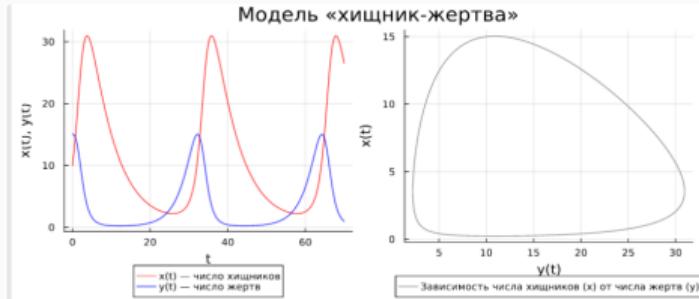
sol =

	timestamp	value1	value2
1	0.0	10.0	15.0
2	0.05	10.2611	15.0193
3	0.1	10.5294	15.0321
4	0.15	10.8049	15.0381
5	0.2	11.0877	15.0372
6	0.25	11.3777	15.0291
7	0.3	11.6751	15.0139
8	0.35	11.9797	14.9911
9	0.4	12.2916	14.9609
10	0.45	12.6106	14.9229
	: more		

sol = solve(prob, dtmax=0.05)

```
[0.0, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8, 0.85, 0.9, 0.95, 1.0, 1.05, 1.1, 1.15, 1.2, 1.25, 1.3, 1.35, 1.4, 1.45, 1.5, 1.55, 1.6, 1.65, 1.7, 1.75, 1.8, 1.85, 1.9, 1.95, 2.0, 2.05, 2.1, 2.15, 2.2, 2.25, 2.3, 2.35, 2.4, 2.45, 2.5, 2.55, 2.6, 2.65, 2.7, 2.75, 2.8, 2.85, 2.9, 2.95, 3.0, 3.05, 3.1, 3.15, 3.2, 3.25, 3.3, 3.35, 3.4, 3.45, 3.5, 3.55, 3.6, 3.65, 3.7, 3.75, 3.8, 3.85, 3.9, 3.95, 4.0, 4.05, 4.1, 4.15, 4.2, 4.25, 4.3, 4.35, 4.4, 4.45, 4.5, 4.55, 4.6, 4.65, 4.7, 4.75, 4.8, 4.85, 4.9, 4.95, 5.0, 5.05, 5.1, 5.15, 5.2, 5.25, 5.3, 5.35, 5.4, 5.45, 5.5, 5.55, 5.6, 5.65, 5.7, 5.75, 5.8, 5.85, 5.9, 5.95, 6.0, 6.05, 6.1, 6.15, 6.2, 6.25, 6.3, 6.35, 6.4, 6.45, 6.5, 6.55, 6.6, 6.65, 6.7, 6.75, 6.8, 6.85, 6.9, 6.95, 7.0, 7.05, 7.1, 7.15, 7.2, 7.25, 7.3, 7.35, 7.4, 7.45, 7.5, 7.55, 7.6, 7.65, 7.7, 7.75, 7.8, 7.85, 7.9, 7.95, 8.0, 8.05, 8.1, 8.15, 8.2, 8.25, 8.3, 8.35, 8.4, 8.45, 8.5, 8.55, 8.6, 8.65, 8.7, 8.75, 8.8, 8.85, 8.9, 8.95, 9.0, 9.05, 9.1, 9.15, 9.2, 9.25, 9.3, 9.35, 9.4, 9.45, 9.5, 9.55, 9.6, 9.65, 9.7, 9.75, 9.8, 9.85, 9.9, 9.95, 10.0, 10.05, 10.1, 10.15, 10.2, 10.25, 10.3, 10.35, 10.4, 10.45, 10.5, 10.55, 10.6, 10.65, 10.7, 10.75, 10.8, 10.85, 10.9, 10.95, 11.0, 11.05, 11.1, 11.15, 11.2, 11.25, 11.3, 11.35, 11.4, 11.45, 11.5, 11.55, 11.6, 11.65, 11.7, 11.75, 11.8, 11.85, 11.9, 11.95, 12.0, 12.05, 12.1, 12.15, 12.2, 12.25, 12.3, 12.35, 12.4, 12.45, 12.5, 12.55, 12.6, 12.65, 12.7, 12.75, 12.8, 12.85, 12.9, 12.95, 13.0, 13.05, 13.1, 13.15, 13.2, 13.25, 13.3, 13.35, 13.4, 13.45, 13.5, 13.55, 13.6, 13.65, 13.7, 13.75, 13.8, 13.85, 13.9, 13.95, 14.0, 14.05, 14.1, 14.15, 14.2, 14.25, 14.3, 14.35, 14.4, 14.45, 14.5, 14.55, 14.6, 14.65, 14.7, 14.75, 14.8, 14.85, 14.9, 14.95, 15.0, 15.05, 15.1, 15.15, 15.2, 15.25, 15.3, 15.35, 15.4, 15.45, 15.5, 15.55, 15.6, 15.65, 15.7, 15.75, 15.8, 15.85, 15.9, 15.95, 16.0, 16.05, 16.1, 16.15, 16.2, 16.25, 16.3, 16.35, 16.4, 16.45, 16.5, 16.55, 16.6, 16.65, 16.7, 16.75, 16.8, 16.85, 16.9, 16.95, 17.0, 17.05, 17.1, 17.15, 17.2, 17.25, 17.3, 17.35, 17.4, 17.45, 17.5, 17.55, 17.6, 17.65, 17.7, 17.75, 17.8, 17.85, 17.9, 17.95, 18.0, 18.05, 18.1, 18.15, 18.2, 18.25, 18.3, 18.35, 18.4, 18.45, 18.5, 18.55, 18.6, 18.65, 18.7, 18.75, 18.8, 18.85, 18.9, 18.95, 19.0, 19.05, 19.1, 19.15, 19.2, 19.25, 19.3, 19.35, 19.4, 19.45, 19.5, 19.55, 19.6, 19.65, 19.7, 19.75, 19.8, 19.85, 19.9, 19.95, 20.0, 20.05, 20.1, 20.15, 20.2, 20.25, 20.3, 20.35, 20.4, 20.45, 20.5, 20.55, 20.6, 20.65, 20.7, 20.75, 20.8, 20.85, 20.9, 20.95, 21.0, 21.05, 21.1, 21.15, 21.2, 21.25, 21.3, 21.35, 21.4, 21.45, 21.5, 21.55, 21.6, 21.65, 21.7, 21.75, 21.8, 21.85, 21.9, 21.95, 22.0, 22.05, 22.1, 22.15, 22.2, 22.25, 22.3, 22.35, 22.4, 22.45, 22.5, 22.55, 22.6, 22.65, 22.7, 22.75, 22.8, 22.85, 22.9, 22.95, 23.0, 23.05, 23.1, 23.15, 23.2, 23.25, 23.3, 23.35, 23.4, 23.45, 23.5, 23.55, 23.6, 23.65, 23.7, 23.75, 23.8, 23.85, 23.9, 23.95, 24.0, 24.05, 24.1, 24.15, 24.2, 24.25, 24.3, 24.35, 24.4, 24.45, 24.5, 24.55, 24.6, 24.65, 24.7, 24.75, 24.8, 24.85, 24.9, 24.95, 25.0, 25.05, 25.1, 25.15, 25.2, 25.25, 25.3, 25.35, 25.4, 25.45, 25.5, 25.55, 25.6, 25.65, 25.7, 25.75, 25.8, 25.85, 25.9, 25.95, 26.0, 26.05, 26.1, 26.15, 26.2, 26.25, 26.3, 26.35, 26.4, 26.45, 26.5, 26.55, 26.6, 26.65, 26.7, 26.75, 26.8, 26.85, 26.9, 26.95, 27.0, 27.05, 27.1, 27.15, 27.2, 27.25, 27.3, 27.35, 27.4, 27.45, 27.5, 27.55, 27.6, 27.65, 27.7, 27.75, 27.8, 27.85, 27.9, 27.95, 28.0, 28.05, 28.1, 28.15, 28.2, 28.25, 28.3, 28.35, 28.4, 28.45, 28.5, 28.55, 28.6, 28.65, 28.7, 28.75, 28.8, 28.85, 28.9, 28.95, 29.0, 29.05, 29.1, 29.15, 29.2, 29.25, 29.3, 29.35, 29.4, 29.45, 29.5, 29.55, 29.6, 29.65, 29.7, 29.75, 29.8, 29.85, 29.9, 29.95, 30.0, 30.05, 30.1, 30.15, 30.2, 30.25, 30.3, 30.35, 30.4, 30.45, 30.5, 30.55, 30.6, 30.65, 30.7, 30.75, 30.8, 30.85, 30.9, 30.95, 31.0, 31.05, 31.1, 31.15, 31.2, 31.25, 31.3, 31.35, 31.4, 31.45, 31.5, 31.55, 31.6, 31.65, 31.7, 31.75, 31.8, 31.85, 31.9, 31.95, 32.0, 32.05, 32.1, 32.15, 32.2, 32.25, 32.3, 32.35, 32.4, 32.45, 32.5, 32.55, 32.6, 32.65, 32.7, 32.75, 32.8, 32.85, 32.9, 32.95, 33.0, 33.05, 33.1, 33.15, 33.2, 33.25, 33.3, 33.35, 33.4, 33.45, 33.5, 33.55, 33.6, 33.65, 33.7, 33.75, 33.8, 33.85, 33.9, 33.95, 34.0, 34.05, 34.1, 34.15, 34.2, 34.25, 34.3, 34.35, 34.4, 34.45, 34.5, 34.55, 34.6, 34.65, 34.7, 34.75, 34.8, 34.85, 34.9, 34.95, 35.0, 35.05, 35.1, 35.15, 35.2, 35.25, 35.3, 35.35, 35.4, 35.45, 35.5, 35.55, 35.6, 35.65, 35.7, 35.75, 35.8, 35.85, 35.9, 35.95, 36.0, 36.05, 36.1, 36.15, 36.2, 36.25, 36.3, 36.35, 36.4, 36.45, 36.5, 36.55, 36.6, 36.65, 36.7, 36.75, 36.8, 36.85, 36.9, 36.95, 37.0, 37.05, 37.1, 37.15, 37.2, 37.25, 37.3, 37.35, 37.4, 37.45, 37.5, 37.55, 37.6, 37.65, 37.7, 37.75, 37.8, 37.85, 37.9, 37.95, 38.0, 38.05, 38.1, 38.15, 38.2, 38.25, 38.3, 38.35, 38.4, 38.45, 38.5, 38.55, 38.6, 38.65, 38.7, 38.75, 38.8, 38.85, 38.9, 38.95, 39.0, 39.05, 39.1, 39.15, 39.2, 39.25, 39.3, 39.35, 39.4, 39.45, 39.5, 39.55, 39.6, 39.65, 39.7, 39.75, 39.8, 39.85, 39.9, 39.95, 40.0, 40.05, 40.1, 40.15, 40.2, 40.25, 40.3, 40.35, 40.4, 40.45, 40.5, 40.55, 40.6, 40.65, 40.7, 40.75, 40.8, 40.85, 40.9, 40.95, 41.0, 41.05, 41.1, 41.15, 41.2, 41.25, 41.3, 41.35, 41.4, 41.45, 41.5, 41.55, 41.6, 41.65, 41.7, 41.75, 41.8, 41.85, 41.9, 41.95, 42.0, 42.05, 42.1, 42.15, 42.2, 42.25, 42.3, 42.35, 42.4, 42.45, 42.5, 42.55, 42.6, 42.65, 42.7, 42.75, 42.8, 42.85, 42.9, 42.95, 43.0, 43.05, 43.1, 43.15, 43.2, 43.25, 43.3, 43.35, 43.4, 43.45, 43.5, 43.55, 43.6, 43.65, 43.7, 43.75, 43.8, 43.85, 43.9, 43.95, 44.0, 44.05, 44.1, 44.15, 44.2, 44.25, 44.3, 44.35, 44.4, 44.45, 44.5, 44.55, 44.6, 44.65, 44.7, 44.75, 44.8, 44.85, 44.9, 44.95, 45.0, 45.05, 45.1, 45.15, 45.2, 45.25, 45.3, 45.35, 45.4, 45.45, 45.5, 45.55, 45.6, 45.65, 45.7, 45.75, 45.8, 45.85, 45.9, 45.95, 46.0, 46.05, 46.1, 46.15, 46.2, 46.25, 46.3, 46.35, 46.4, 46.45, 46.5, 46.55, 46.6, 46.65, 46.7, 46.75, 46.8, 46.85, 46.9, 46.95, 47.0, 47.05, 47.1, 47.15, 47.2, 47.25, 47.3, 47.35, 47.4, 47.45, 47.5, 47.55, 47.6, 47.65, 47.7, 47.75, 47.8, 47.85, 47.9, 47.95, 48.0, 48.05, 48.1, 48.15, 48.2, 48.25, 48.3, 48.35, 48.4, 48.45, 48.5, 48.55, 48.6, 48.65, 48.7, 48.75, 48.8, 48.85, 48.9, 48.95, 49.0, 49.05, 49.1, 49.15, 49.2, 49.25, 49.3, 49.35, 49.4, 49.45, 49.5, 49.55, 49.6, 49.65, 49.7, 49.75, 49.8, 49.85, 49.9, 49.95, 50.0, 50.05, 50.1, 50.15, 50.2, 50.25, 50.3, 50.35, 50.4, 50.45, 50.5, 50.55, 50.6, 50.65, 50.7, 50.75, 50.8, 50.85, 50.9, 50.95, 51.0, 51.05, 51.1, 51.15, 51.2, 51.25, 51.3, 51.35, 51.4, 51.45, 51.5, 51.55, 51.6, 51.65, 51.7, 51.75, 51.8, 51.85, 51.9, 51.95, 52.0, 52.05, 52.1, 52.15, 52.2, 52.25, 52.3, 52.35, 52.4, 52.45, 52.5, 52.55, 52.6, 52.65, 52.7, 52.75, 52.8, 52.85, 52.9, 52.95, 53.0, 53.05, 53.1, 53.15, 53.2, 53.25, 53.3, 53.35, 53.4, 53.45, 53.5, 53.55, 53.6, 53.65, 53.7, 53.75, 53.8, 53.85, 53.9, 53.95, 54.0, 54.05, 54.1, 54.15, 54.2, 54.25, 54.3, 54.35, 54.4, 54.45, 54.5, 54.55, 54.6, 54.65, 54.7, 54.75, 54.8, 54.85, 54.9, 54.95, 55.0, 55.05, 55.1, 55.15, 55.2, 55.25, 55.3, 55.35, 55.4, 55.45, 55.5, 55.55, 55.6, 55.65, 55.7, 55.75, 55.8, 55.85, 55.9, 55.95, 56.0, 56.05, 56.1, 56.15, 56.2, 56.25, 56.3, 56.35, 56.4, 56.45, 56.5, 56.55, 56.6, 56.65, 56.7, 56.75, 56.8, 56.85, 56.9, 56.95, 57.0, 57.05, 57.1, 57.15, 57.2, 57.25, 57.3, 57.35, 57.4, 57.45, 57.5, 57.55, 57.6, 57.65, 57.7, 57.75, 57.8, 57.85, 57.9, 57.95, 58.0, 58.05, 58.1, 58.15, 58.2, 58.25, 58.3, 58.35, 58.4, 58.45, 58.5, 58.55, 58.6, 58.65, 58.7, 58.75, 58.8, 58.85, 58.9, 58.95, 59.0, 59.05, 59.1, 59.15, 59.2, 59.25, 59.3, 59.35, 59.4, 59.45, 59.5, 59.55, 59.6, 59.65, 59.7, 59.75, 59.8, 59.85, 59.9, 59.95, 60.0, 60.05, 60.1, 60.15, 60.2, 60.25, 60.3, 60.35, 60.4, 60.45, 60.5, 60.55, 60.6, 60.65, 60.7, 60.75, 60.8, 60.85, 60.9, 60.95, 61.0, 61.05, 61.1, 61.15, 61.2, 61.25, 61.3, 61.35, 61.4, 61.45, 61.5, 61.55, 61.6, 61.65, 61.7, 61.75, 61.8, 61.85, 61.9, 61.95, 62.0, 62.05, 62.1, 62.15, 62.2, 62.25, 62.3, 62.35, 62.4, 62.45, 62.5, 62.55, 62.6, 62.65, 62.7, 62.75, 62.8, 62.85, 62.9, 62.95, 63.0, 63.05, 63.1, 63.15, 63.2, 63.25, 63.3, 63.35, 63.4, 63.45, 63.5, 63.55, 63.6, 63.65, 63.7, 63.75, 63.8, 63.85, 63.9, 63.95, 64.0, 64.05, 64.1, 64.15, 64.2, 64.25, 64.3, 64.35, 64.4, 64.45, 64.5, 64.55, 64.6, 64.65, 64.7, 64.75, 64.8, 64.85, 64.9, 64.95, 65.0, 65.05, 65.1, 65.15, 65.2, 65.25, 65.3, 65.35, 65.4, 65.45, 65.5, 65.55, 65.6, 65.65, 65.7, 65.75, 65.8, 65.85, 65.9, 65.95, 66.0, 66.05, 66.1, 66.15, 66.2, 66.25, 66.3, 66.35, 66.4, 66.45, 66.5, 66.55, 66.6, 66.65, 66.7, 66.75, 66.8, 66.85, 66.9, 66.95, 67.0, 67.05, 67.1, 67.15, 67.2, 67.25, 67.3, 67.35, 67.4, 67.45, 67.5, 67.55, 67.6, 67.65, 67.7, 67.75, 67.8, 67.85, 67.9, 67.95, 68.0, 68.05, 68.1, 68.15, 68.2, 68.25, 68.3, 68.35, 68.4, 68.45, 68.5, 68.55, 68.6, 68.65, 68.7, 68.75, 68.8, 68.85, 68.9, 68.95, 69.0, 69.05, 69.1, 69.15, 69.2, 69.25, 69.3, 69.35, 69.4, 69.45, 69.5, 69.55, 69.6, 69.65, 69.7, 69.75, 69.8, 69.85, 69.9, 69.95, 70.0, 70.05, 70.1, 70.15, 70.2, 70.25, 70.3, 70.35, 70.4, 70.45, 70.5, 70.55, 70.6, 70.65, 70.7, 70.75, 70.8, 70.85, 70.9, 70.95, 71.0, 71.05, 71.1, 71.15, 71.2, 71.25, 71.3, 71.35, 71.4, 71.45, 71.5, 71.55, 71.6, 71.65, 71.7, 71.75, 71.8, 71.85, 71.9, 71.95, 72.0, 72.05, 72.1, 72.15, 72.2, 72.25, 72.3, 72.35, 72.4, 72.45, 72.5, 72.55, 72.6, 72.65, 72.7, 72.75, 72.8, 72.85, 72.9, 72.95, 73.0, 73.05, 73.1, 73.15, 73.2, 73.25, 73.3, 73.35, 73.4, 73.45, 73.5, 73.55, 73.6, 73.65, 73.7, 73.75, 73.8, 73.85, 73.9, 73.95, 74.0, 74.05, 74.1, 74.15, 74.2, 74.25, 74.3, 74.35, 74.4, 74.45, 74.5, 74.55, 74.6, 74.65, 74.7, 74.75, 74.8, 74.85, 74.9, 74.95, 75.0, 75.05, 75.1, 75.15, 75.2, 75.25, 75.3, 75.35, 75.4, 75.45, 75.5, 75.55, 75.6, 75.65, 75.7, 75.75, 75.8, 75.85, 75.9, 75.95, 76.0, 76.05, 76.1, 76.15, 76.2, 76.25, 76.3, 76.35, 76.4, 76.45, 76.5, 76.55, 76.6, 76.65, 76.7, 76.75, 76.8, 76.85, 76.9, 76.95, 77.0, 77.05, 77.1, 77.15, 77.2, 77.25, 77.3, 77.35, 77.4, 77.45, 77.5, 77.55, 77.6, 77.65, 77.7, 77.75, 77.8, 77.85, 77.9, 77.95, 78.0, 78.05, 78.1, 78.15, 78.2, 78.25, 78.3, 78.35, 78.4, 78.45, 78.5, 78.55, 78.6, 78.65, 78.7, 78.75, 78.8, 78.85, 78.9, 78.95, 79.0, 79.05, 79.1, 79.15, 79.2, 79.25, 79.3, 79.35, 79.4, 79.45, 79.5, 79.55, 79.6, 79.65, 79.7, 79.75, 79.8, 79.85, 79.9, 79.95, 80.0, 80.05, 80.1, 80.15, 80.2, 80.25, 80.3, 80.35, 80.4, 80.45, 80.5, 80.55, 80.6, 80.65, 80.7, 80.75, 80.8, 80.85, 80.9, 80.95, 81.0, 81.05, 81.1, 81.15, 81.2, 81.25, 81.3, 81.35, 81.4, 81.45, 81.5, 81.55, 81.6, 81.65, 81.7, 81.75, 81.8, 81.85, 81.9, 81.95, 82.0, 82.05, 82.1, 82.15, 82.2, 82.25, 82.3, 82.35, 82.4, 82.45, 82.5, 82.55, 82.6, 82.65, 82.7, 82.75, 82.8, 82.85, 82.9, 82.95, 83.0, 83.05, 83.1, 83.15, 83.2, 83.25, 83.3, 83.35, 83.4, 83.45, 83.5, 83.55, 83.6, 83.65, 83.7, 83.75, 83.8, 83.85, 83.9, 83.95, 84.0, 84.05, 84.1, 84.15, 84.2, 84.25, 84.3, 84.35, 84.4, 84.45, 84.5, 84.55, 84.6, 84.65, 84.7, 84.75, 84.8, 84.85, 84.9, 84.95, 85.0, 85.05, 85.1, 
```

Графики задания №1



```
begin
    fig = Plots.plot(
        layout=(1, 2),
        dpi=150,
        grid=:xy,
        gridcolor=:black,
        gridwidth=1,
        # aspect_ratio=:equal,
        size=(800, 400),
        legend=:outerbottom,
        plot_title="Модель «хищник-жертва»"
    )
    Plots.plot!(
        fig[1],
        time,
        [xx, yy],
        color=[:red ;:blue],
        xlabel="t",
        ylabel="x(t), y(t)",
        label=["x(t) — число хищников" "y(t) — число жертв"]
    )
    Plots.plot!(
        fig[2],
        yy,
        xx,
        color=[:grey],
        xlabel="y(t)",
        ylabel="x(t)",
        label="Зависимость числа хищников ( $x$ ) от числа жертв ( $y$ )"
    )

```

Измененный блок кода для задания №2. Получившиеся графики

T

Период времени

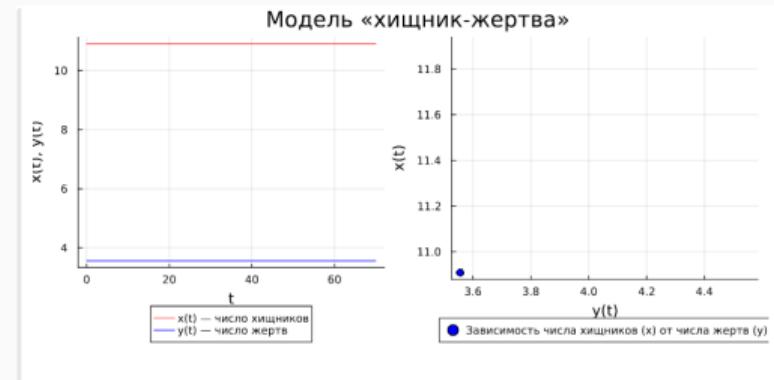
```
begin
  const c = 0.16
  const d = 0.045
  const a = 0.36
  const b = 0.033
  const x0 = a / b
  const y0 = c / d

  @show x0
  @show y0

  "Начальные условия: ue[1] -- x0, ue[2] -- y0"
  ue = [x0, y0]

  "Период времени"
  T = (0.0, 70.0)
end
```

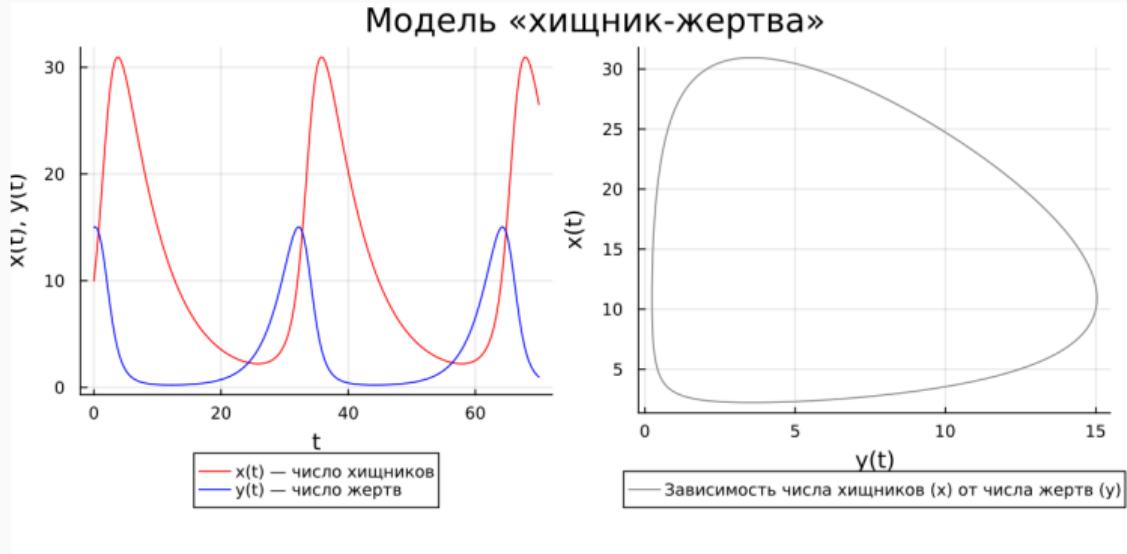
x0 = 10.909090909090908
y0 = 3.5555555555555556



Julia

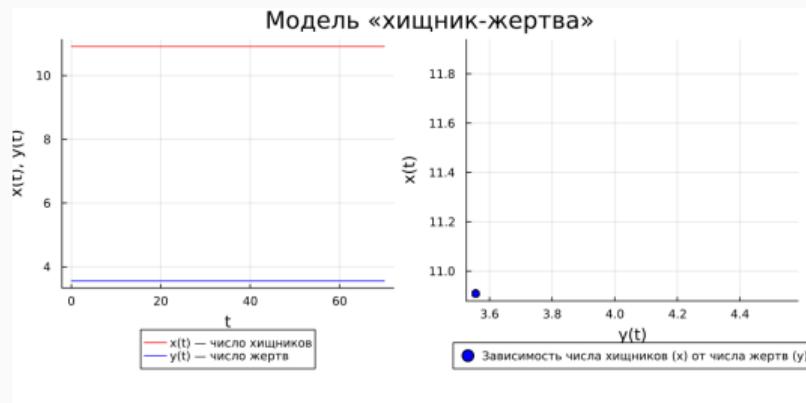
Код задания №1. Получившиеся графики

```
1 using DifferentialEquations
2 using Plots
3
4 const c = 0.16
5 const d = 0.045
6 const a = 0.36
7 const b = 0.033
8 const xx = 10
9 const yy = 15
10
11 "Начальные условия: u[1] -- x0, u[2] -- y0"
12 u0 = [xx, yy]
13
14 "Период времени"
15 T = (0.0, 70.0)
16
17 "Правая часть нашей системы, p, t не используются, u[1] -- x, u[2] -- y"
18 function F!(du, u, p, t)
19     du[1] = -c * u[1] + d * u[1] * u[2]
20     du[2] = a * u[2] - b * u[1] * u[2]
21 end
22
23
24 prob = ODEProblem(F!, u0, (T))
25 sol = solve(prob, dtmax=0.05)
26
27 const xx = []
28 const yy = []
29 for t in sol.t
30     x, y = u
31     push!(xx, x)
32     push!(yy, y)
33 end
34 time = sol.t
35
36 fig = Plots.plot(
37     layout=1, 2,
38     dpi=150,
39     grid=:xy,
40     gridcolor=:black,
41     griddash=[1, 0],
42     aspect_ratio=:equal,
43     size=(800, 400),
44     legend=:outerbottom,
45     plot_title="Модель «хищник-жертва»",
46 )
47
48 Plots.plot(
49     fig[1],
50     time,
51     [xx, yy],
52     color=[:red, :blue],
53     xlabel="t",
54     ylabel="x(t), y(t)",
55     title="x(t) — число хищников, y(t) — число жертв"
56 )
57
58 Plots.plot(
59     fig[2],
60     yy,
61     xx,
62     color=[:grey],
63     xlabel="y(t)",
64     ylabel="x(t)",
65     title="Зависимость числа хищников (x) от числа жертв (y)"
66 )
67 savefig(fig, "../dat5_1")
```



Измененный блок кода для задания №2. Получившиеся графики

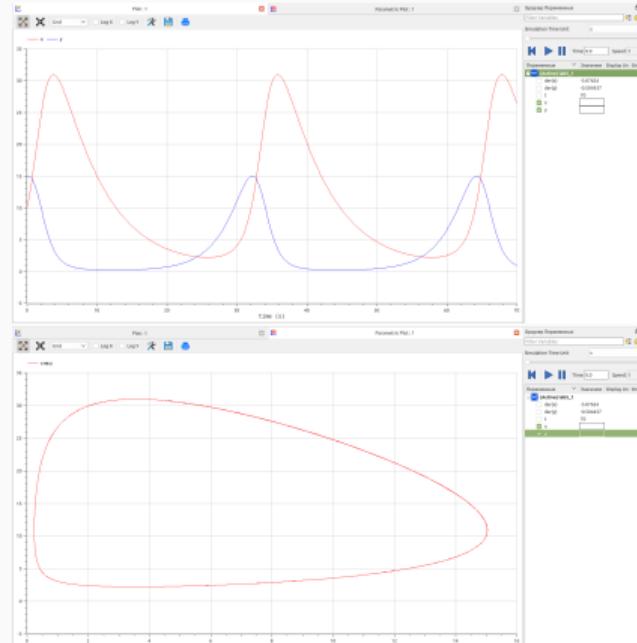
```
4  const c = 0.16
5  const d = 0.045
6  const a = 0.36
7  const b = 0.033
8  const x0 = a / b
9  const y0 = c / d
10
11 @show x0
12 @show y0
13
14 "Начальные условия: u0[1] -- x0, u0[2] -- y0"
15 u0 = [x0, y0]
```



OpenModelica

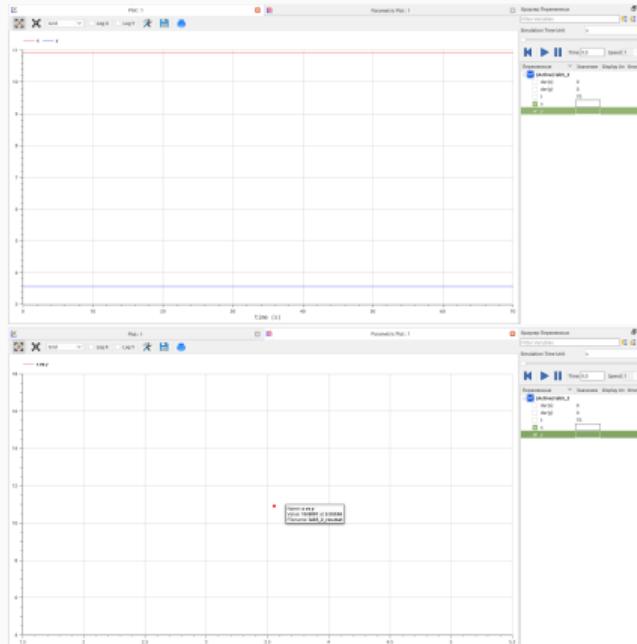
Код задания №1. Получившиеся графики

```
1 model lab5_1
2   constant Real c = 0.16;
3   constant Real d = 0.045;
4   constant Real a = 0.36;
5   constant Real b = 0.033;
6   Real t = time;
7   Real x(t);
8   Real y(t);
9 initial equation
10  x = 10;
11  y = 15;
12 equation
13  der(x) = -c * x + d * x * y;
14  der(y) = a * y - b * x * y;
15  annotation(experiment(StartTime=0, StopTime=70, Interval = 0.05));
16 end lab5_1;
```



Код задания №2. Получившиеся графики

```
1 model lab5_2
2   constant Real c = 0.16;
3   constant Real d = 0.045;
4   constant Real a = 0.36;
5   constant Real b = 0.033;
6   Real t = time;
7   Real x(t);
8   Real y(t);
9 initial equation
10   x = a / b;
11   y = c / d;
12 equation
13   der(x) = -c * x + d * x * y;
14   der(y) = a * y - b * x * y;
15   annotation(experiment(StartTime=0, StopTime=70, Interval = 0.05));
16 end lab5_2;
```



Результаты

Результаты

- Созданы математические модели Лотки-Вольтерры с помощью данных языков.
- Построены графики состояния систем в соответствии с поставленными задачами.

Вывод

Продолжил знакомство с функционалом языка программирования Julia и языка моделирования Modelica, а также с функционалом программного обеспечения OpenModelica и интерактивного блокнота Pluto. Используя эти средства, построил математические модели «хищник-жертва» (модели Лотки-Вольтерры).