

# Physical Modelling with ModelVision, a DAE Simulator with Features for Hybrid Automata

## MVStadium Project

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**MyStadium**  
<http://www.mvstadium.com>  
Model based design of complex dynamical systems

Схема системы

МОДЕЛИРОВАНИЕ СИСТЕМ  
на базе вычислительного моделирования

Structure: [Система]

3D animation

model - c...

3D animation



# MvStudium

is the tool with  
graphical, UML-based  
language for  
modeling and simulation  
of complex dynamical systems  
(Object Oriented Modeling)

<http://www.mvstudium.com>



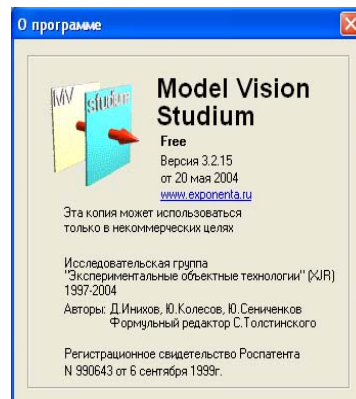
Complex dynamical  
system is

Large scale,  
Hierarchical,  
Event-driven (hybrid)  
mathematical model  
with dynamically changed  
number of components



# The Model Vision Family

- MV 2.1 (1994-96)
- MVS 3.0 (1996-2003)
- MVS 4.X - 2004-????



Ole-Johan Dahl, Bjorn Myrhaug, Kristen Nygaard  
SIMULA 67

Glushkov V., Gusev V., Marjanovich T., Sachnjak M.  
Tools for modeling mixed continuous and discrete systems.  
1975

Booch G, Jacobson I., Rumbaugh J.  
The unified modeling language for object-oriented modeling  
1977

A. Alan Pritsker.  
Introduction to Simulation and SLAM II.  
1986



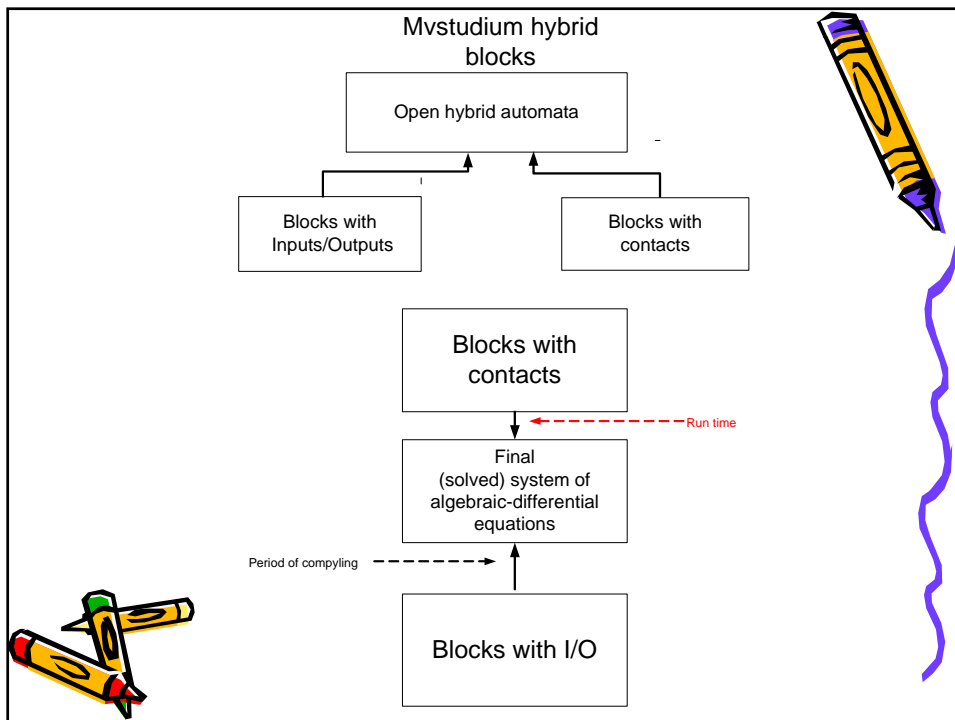
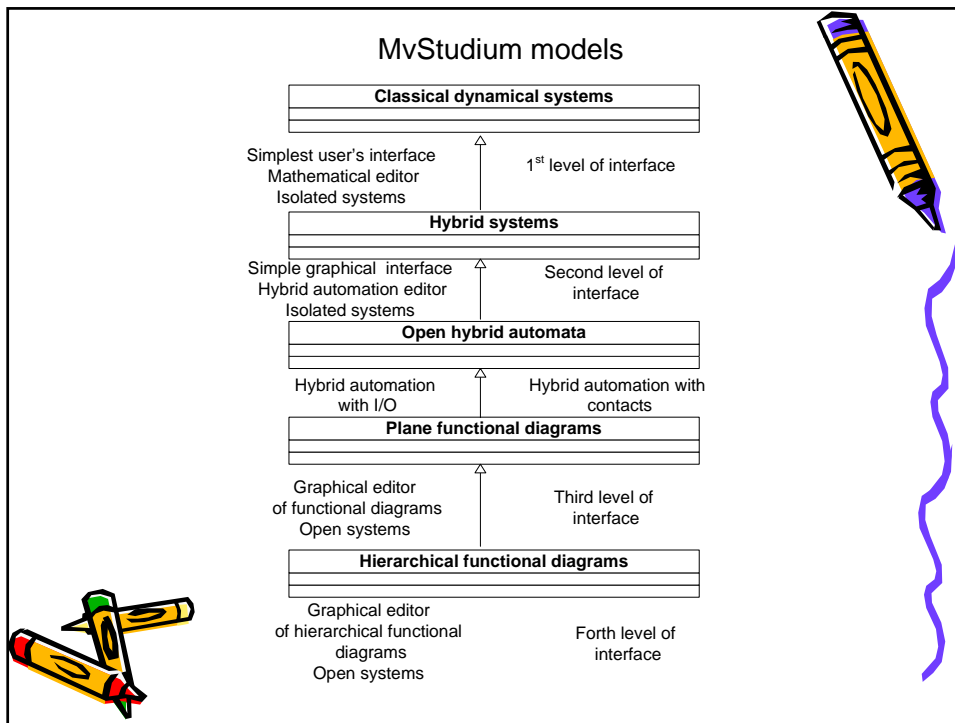
MvStudium

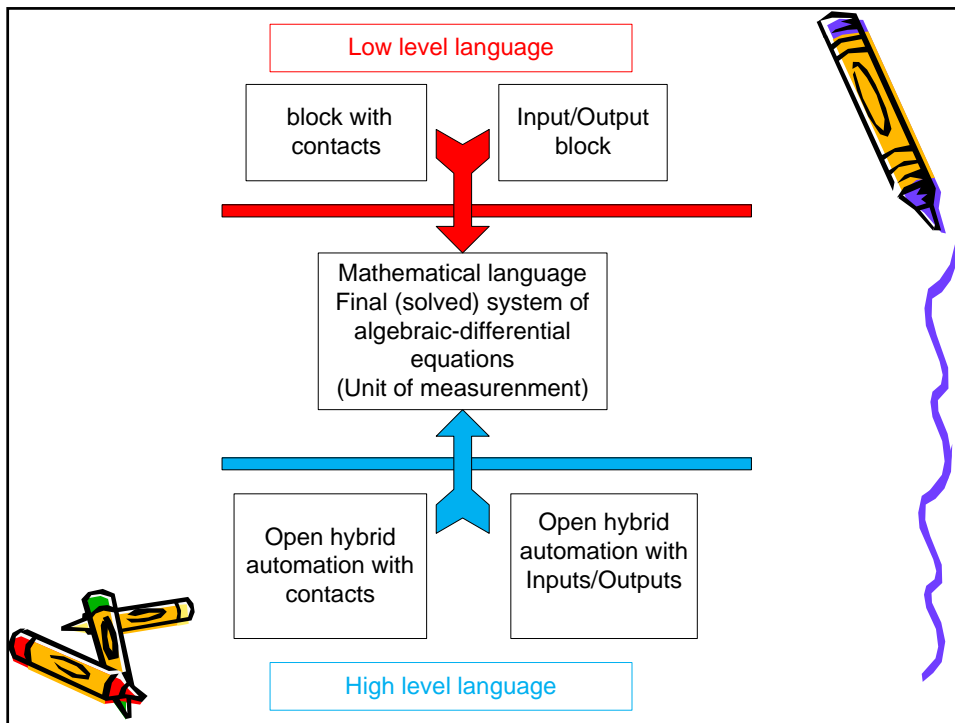
Maler O., Manna Z, Pnueli A.  
A formal approach to hybrid systems.  
1992



Fillipov A.  
Differential equations with discontinues right-hand side.  
1985







MvStudium's simplest mathematical models

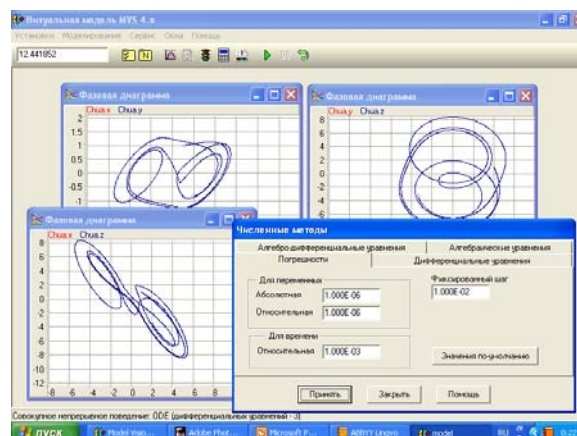
# Classical dynamical system (continuous time)

is a system of differential equations

$$\frac{dx}{dt} = f(x), x \in \mathbb{R}^n, x(0) = x^0$$

with right hand side  $f(x)$ , ensuring  
existence and uniqueness of the solution

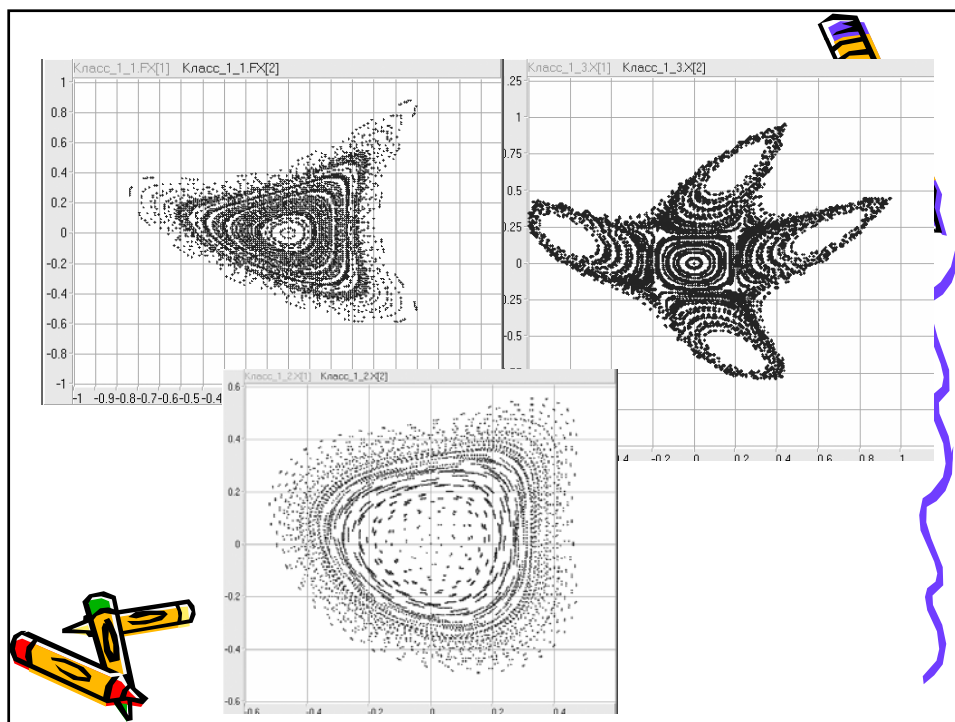
$$x = x(t; x^0)$$



# Discreet dynamical systems (discreet time). Difference equations



$$\begin{cases} x_{n+1} = x_n \cdot \cos \alpha - (y_n - x_n^2) \cdot \sin \alpha \\ y_{n+1} = x_n \cdot \sin \alpha - (y_n - x_n^2) \cdot \cos \alpha \end{cases}$$



# Discrete-continuous systems

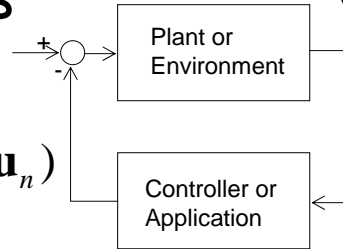
- Object of control

$$\frac{dx}{dt} = \mathbf{f}(\mathbf{x}(t), \mathbf{u}_n)$$

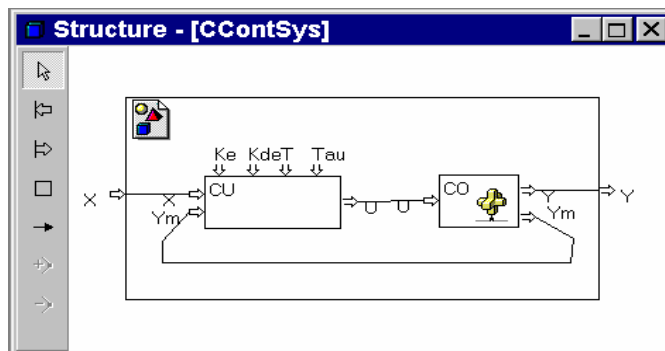
- Control

$$\mathbf{u}_{n+1} = \mathbf{G}(\mathbf{x}(t_n), \mathbf{u}_n),$$

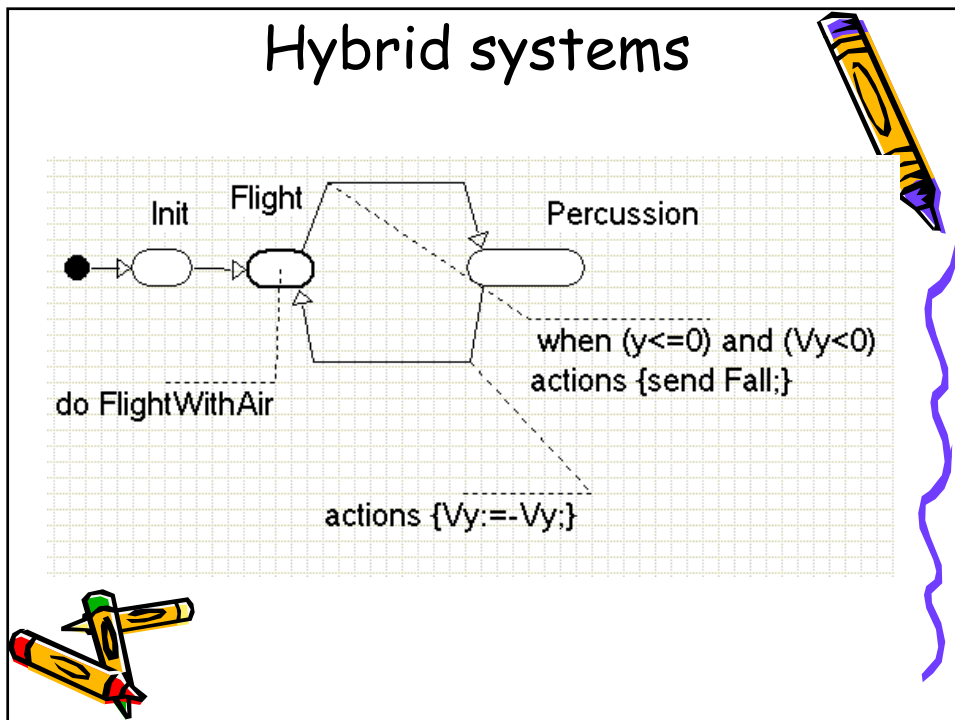
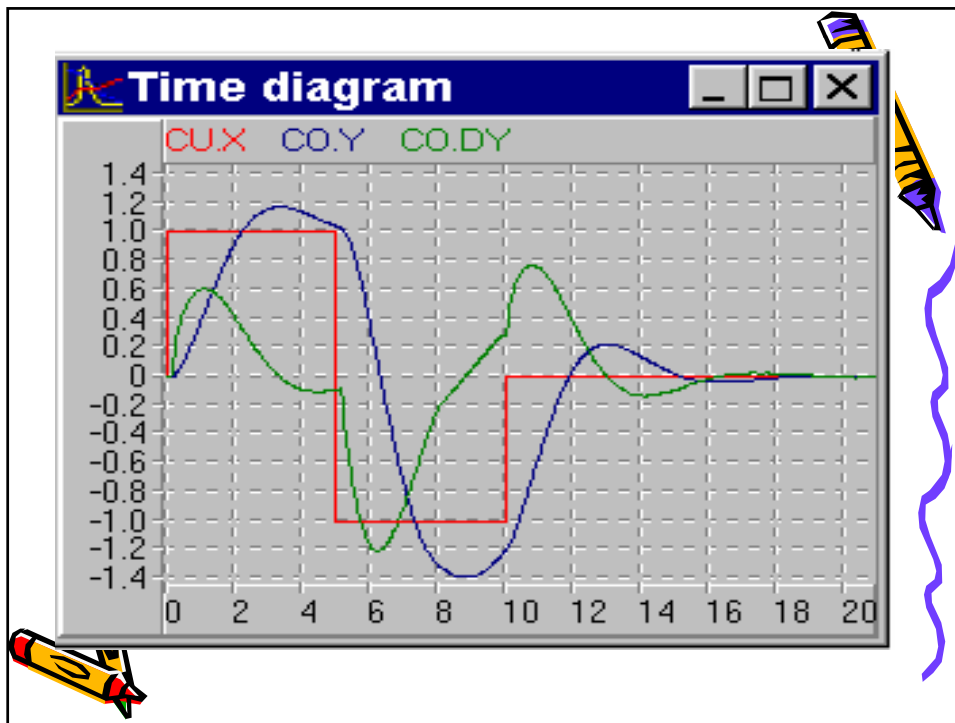
$$\mathbf{u}_n = \mathbf{u}(t_n), t_{n+1} = t_n + h,$$



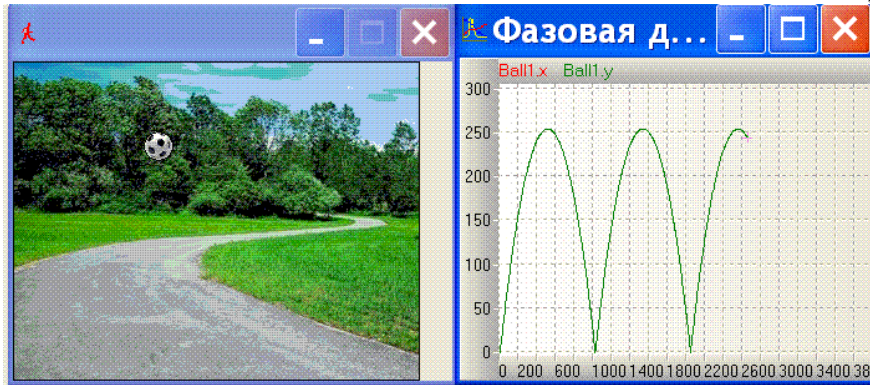
# Control system



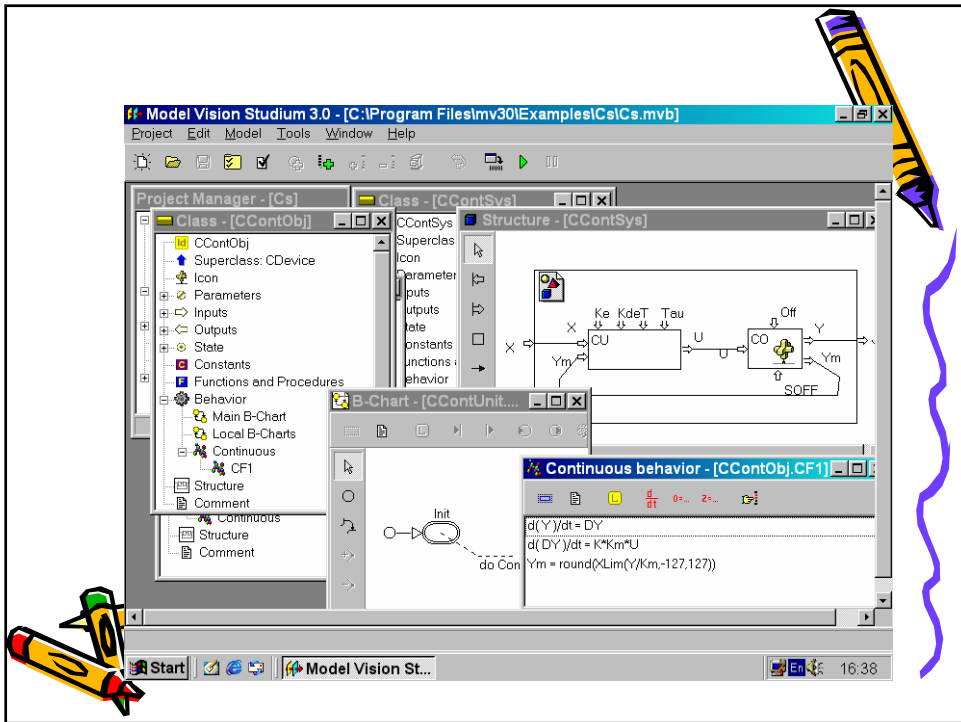
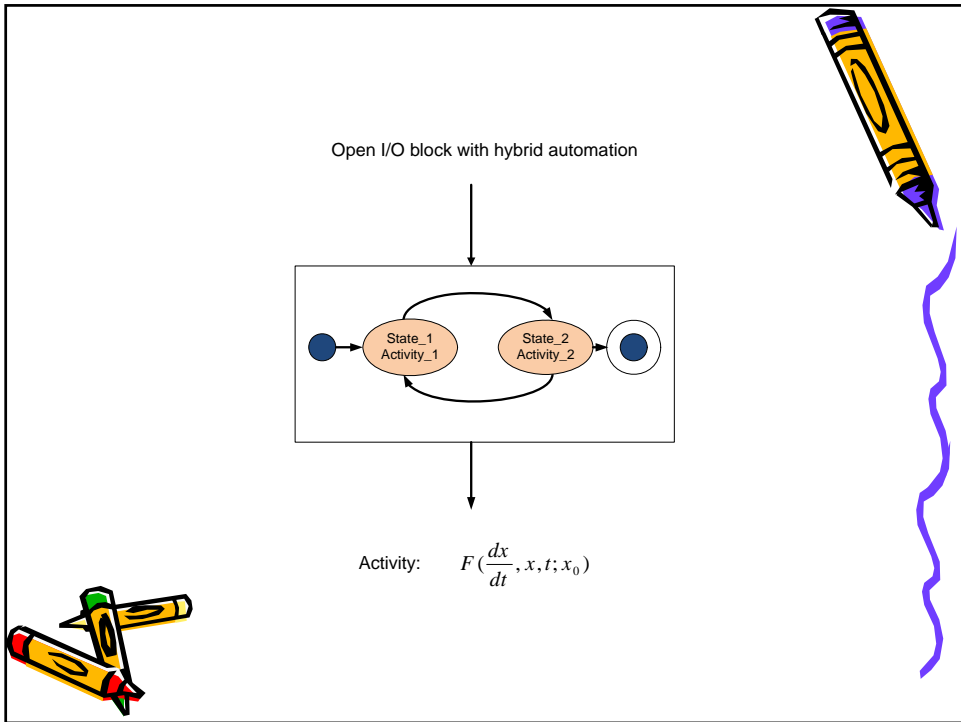


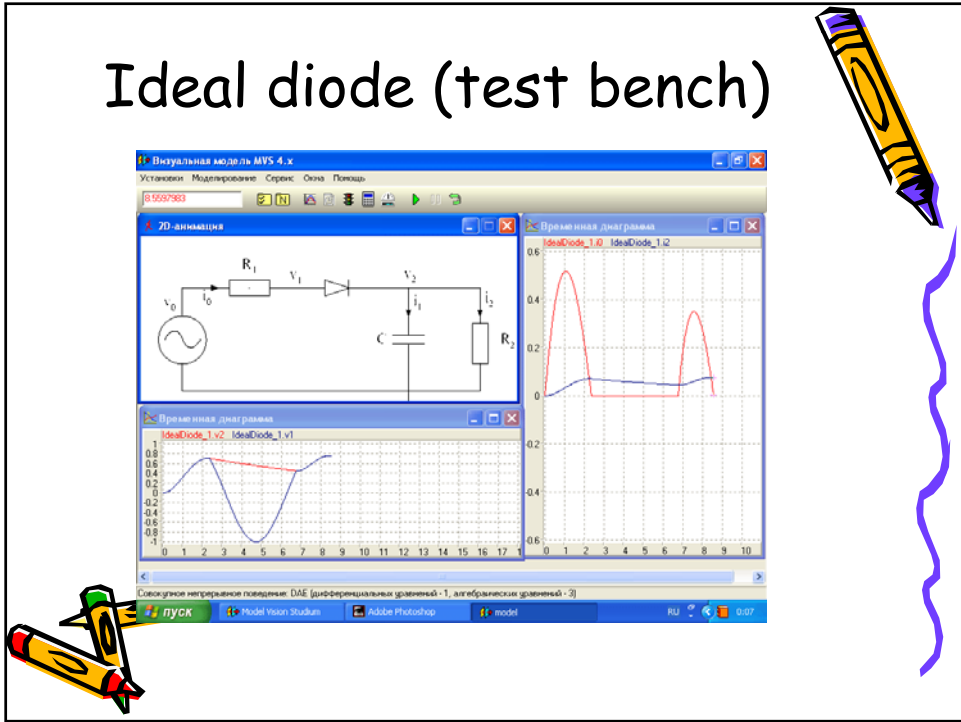
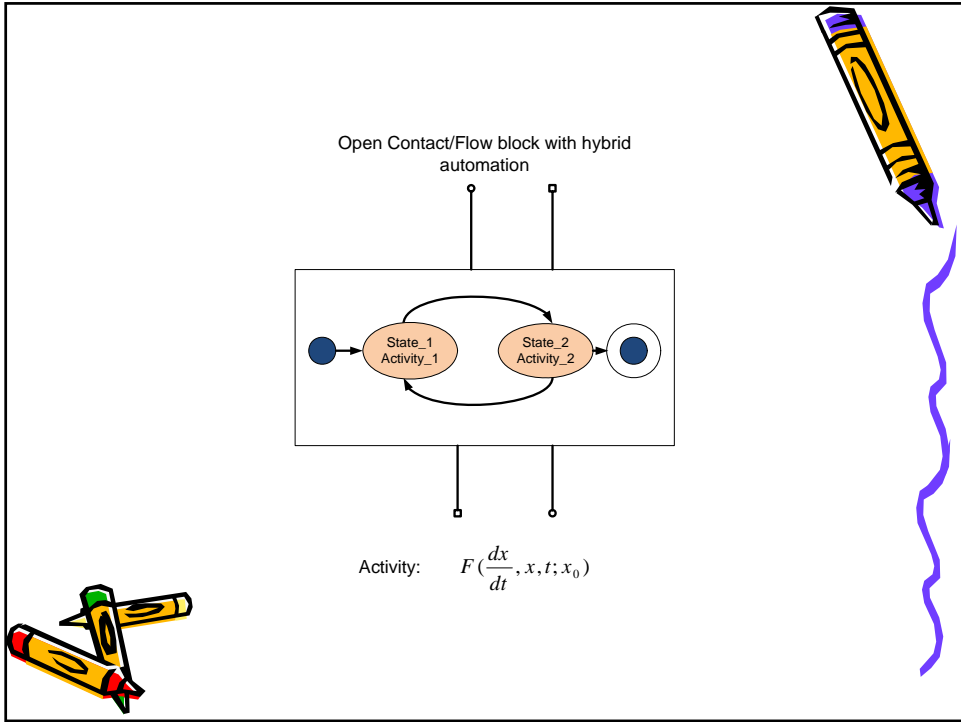


# Bouncing ball

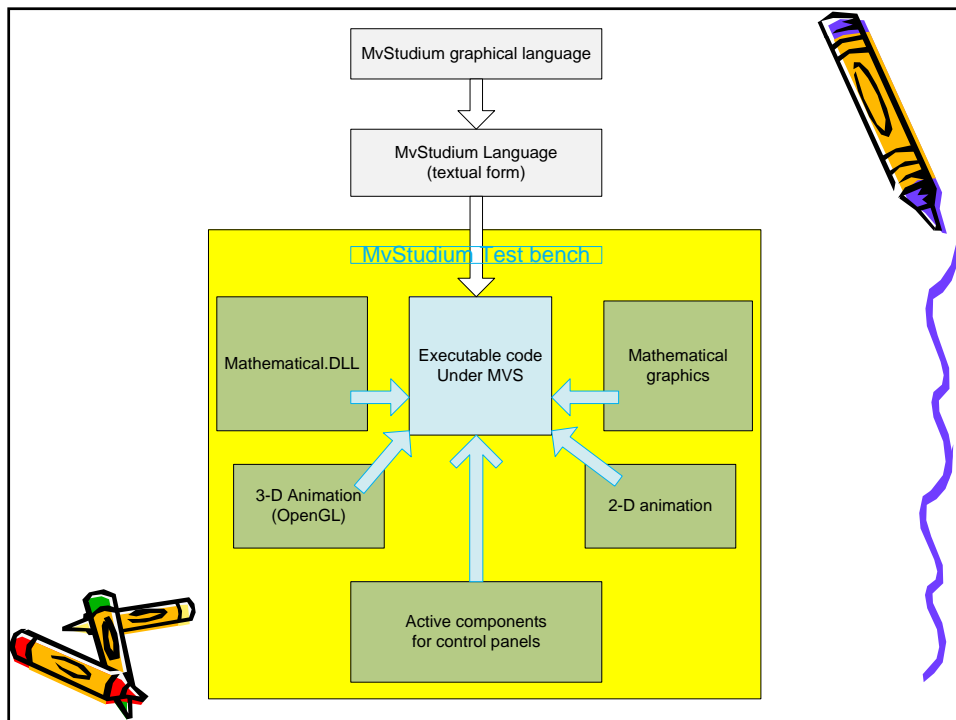


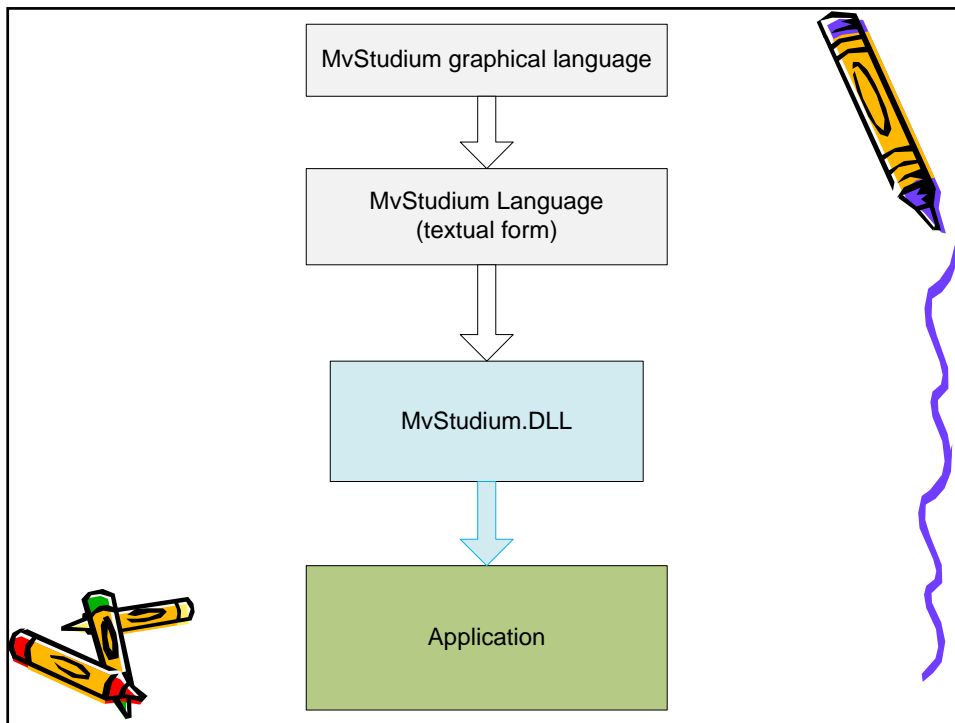
# MvStudium's Blocks





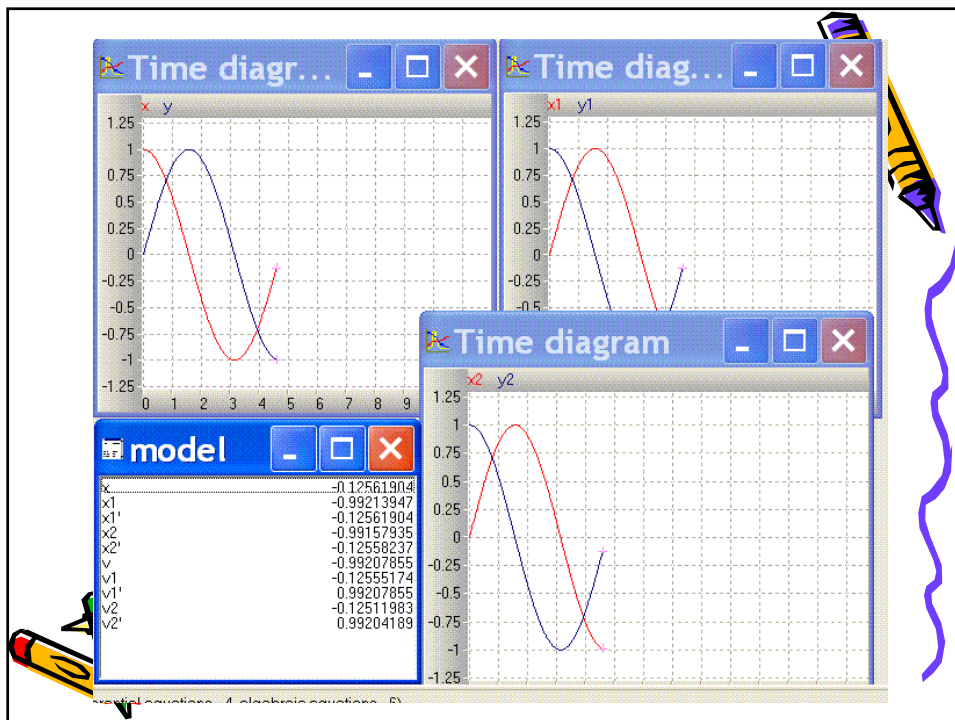
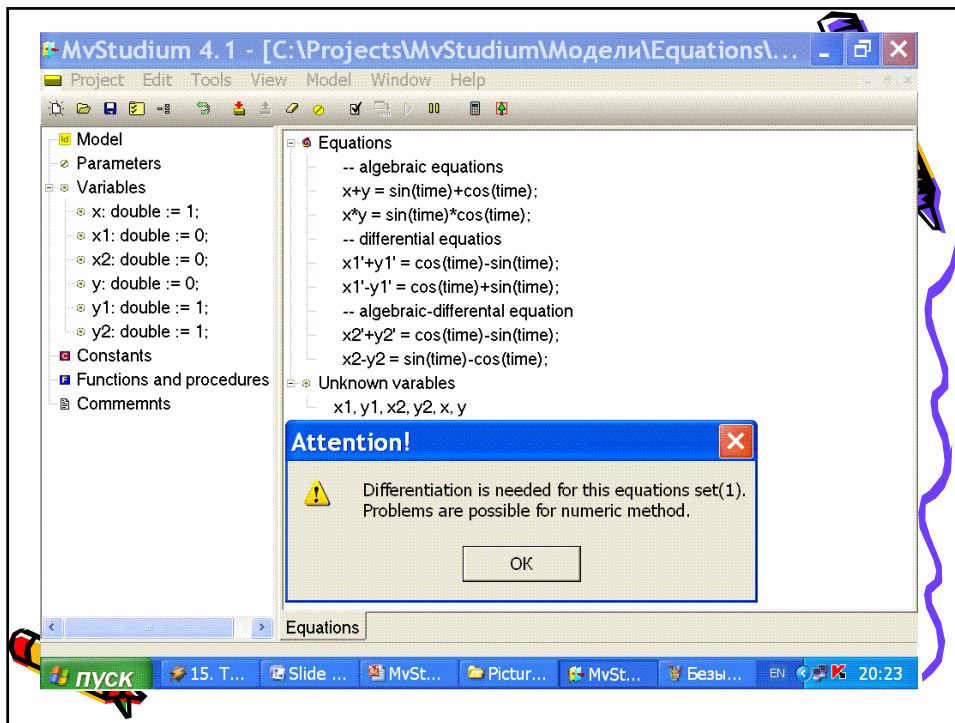
# MvStudium's executives





## Numerical problems

- Nonlinear Algebraic Equations
- Ordinary Differential Equations
- Algebraic-Differential Equations



## MVS numerical software

- Linpack, Eispack, Sparspak, MA28
- ODEPACK, Dopri5, dopri853, Radau5, Dassel



## MVS Numerical Library is used

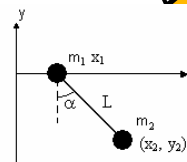
- |                   |                   |
|-------------------|-------------------|
| • Fortran version | • Java version    |
| in                | in                |
| MvStudium 4.x     | AnyLogic (Russia) |
|                   | Open Source       |
|                   | Physics (USA)     |





# Examples

## Example 1: Pendulum with free point of suspension


$$(m_1+m_2) \cdot \frac{d^2 x_1}{dt^2} + m_2 \cdot L \cdot \cos(\text{Alpha}) \cdot \frac{d^2 \text{Alpha}}{dt^2} - m_2 \cdot L \cdot \sin(\text{Alpha}) \cdot \frac{d \text{Alpha}}{dt}^2 = 0$$
$$\cos(\text{Alpha}) \cdot \frac{d^2 x_1}{dt^2} + L \cdot \frac{d^2 \text{Alpha}}{dt^2} + g \cdot \sin(\text{Alpha}) = 0$$
$$x_2 = x_1 + L \cdot \sin(\text{Alpha})$$
$$y_2 = -L \cdot \cos(\text{Alpha})$$

Editor of mathematics models

## Example 2: breaking pendulum (bottom-up design)

**oscillation (First Class)**

$$\frac{d^2 \text{Alpha}}{dt^2} = -g \cdot \sin(\text{Alpha})$$

**Free fall (Second Class)**

$$\frac{d^2 y}{dt^2} = -g$$

$$\frac{d^2 x}{dt^2} = 0$$

**Final model**

```

do Flight(V0=V, Teta0=Teta, x0=X, y0=Y)
  S0sc --> SFlight
  SFlight --> after 1
  when Break
  actions {
    X:=S0sc.L*sin(S0sc.Alpha);
    Y:=S0sc.L*cos(S0sc.Alpha);
    V:=d(S0sc.Alpha)/dt*S0sc.L;
    Teta:=S0sc.Alpha;
  }
do Pendulum(Alpha0=Alpha, Omega0=Omega)
  
```

## Example 3: statistical test: shell flight

A shell flight

Equations

**Statistical experiment**

```

when (F.y<=0) and (d(F.y)/dt<0)
  actions {L:=F.x;}
  do Flight(V0=V, Teta0=Teta)
  
```

**System of equations**

- $m \cdot d^2(y)/dt = F_y \cdot m \cdot g$
- $m \cdot d^2(x)/dt = F_x$
- Исходные переменные  $y, x$
- Начальные значения производных
  - $dy/dt = V0 \cdot \sin(Teta0)$
  - $dx/dt = V0 \cdot \cos(Teta0)$

**Example 3A: inheritance. Flight without friction and with friction.**

Редактор Формул - [FlightInAir]  
 Файл Правка Вставка Вид Помощь

$$\therefore m \cdot \frac{d^2 y}{dt^2} = F_y - m \cdot g$$

$$\therefore m \cdot \frac{d^2 x}{dt^2} = F_x$$

$$V = \sqrt{\left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2}$$

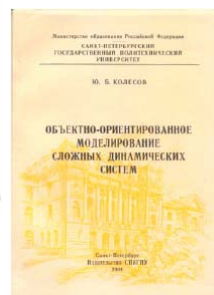
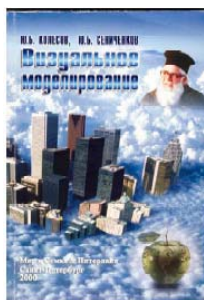
$$\cos Teta = \frac{\frac{dx}{dt}}{V} \quad \sin Teta = \frac{\frac{dy}{dt}}{V}$$

$$F = C_x \cdot S_m \cdot \frac{R_0 \cdot V^2}{2}$$

$$F_x = F \cdot \cos Teta \quad F_y = F \cdot \sin Teta$$

Готово

**Books**



# Textbooks

The image displays three textbooks from the 'Modeling of Systems' series, authored by Yu. B. Kalashnikov and Yu. B. Sidorov. The books are:

- Modeling of Systems: Dynamic and Hybrid Systems** (Учебное пособие): Focuses on dynamic and hybrid systems, including topics like computer modeling, hybrid systems as generalized dynamic systems, and modern methods of graphical modeling and research of hierarchical multi-component dynamic systems.
- Modeling of Systems: Object-Oriented Approach** (Учебное пособие): Covers object-oriented modeling, computer modeling of dynamic systems, modeling on the basis of hybrid automata, and basic directions in graphical computer modeling.
- Modeling of Systems: Practice of Computer Modeling** (Учебное пособие): Includes the development of models of complex dynamic systems in the visual modeling environment ModelSim, types of computational experiments, learning materials for computer modeling, and a CD-ROM with modeling environments and demonstration versions.

# Thanks!

<http://www.mvstudium.com>