Visual Simulation of Electromechanical Systems in Ptolemy II

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Ptolemy Miniconference
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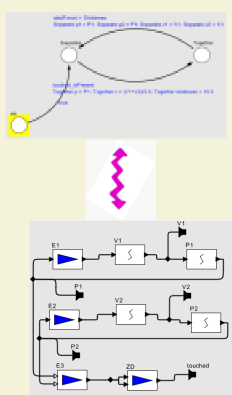
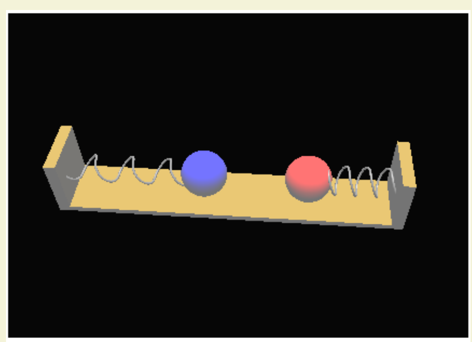
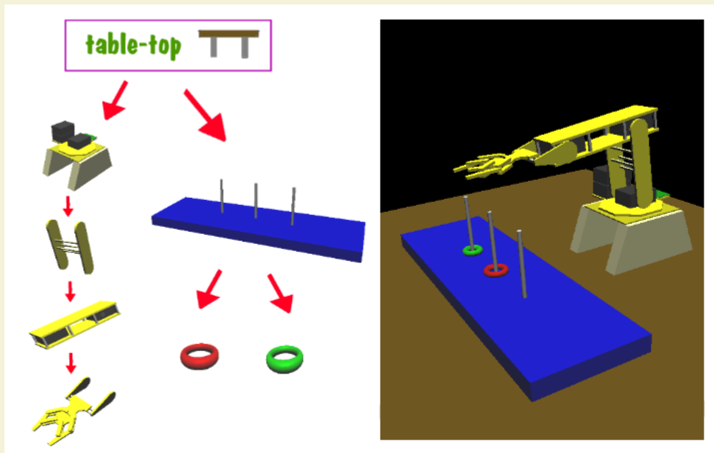
Sticky Masses Revisited

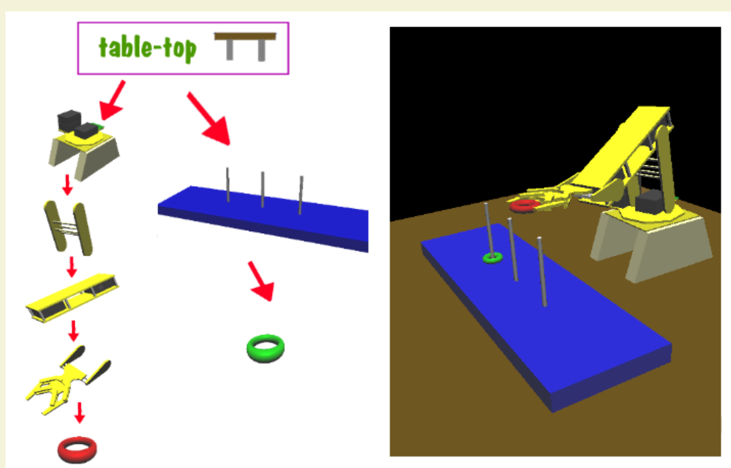




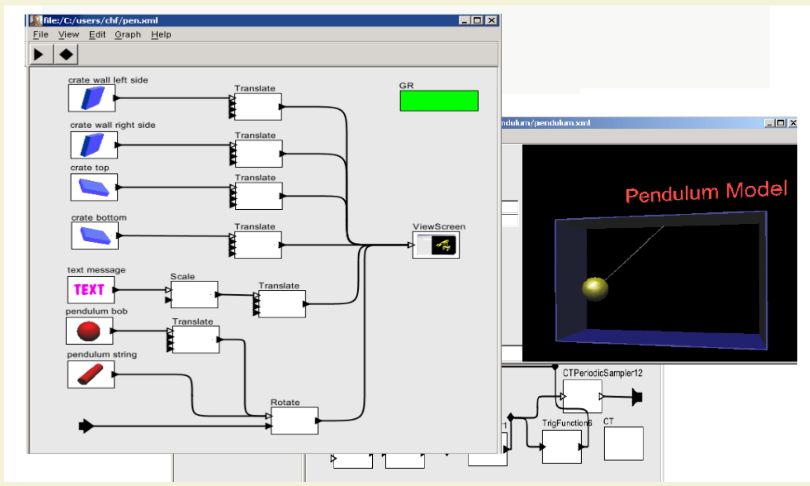
Scene Graphs



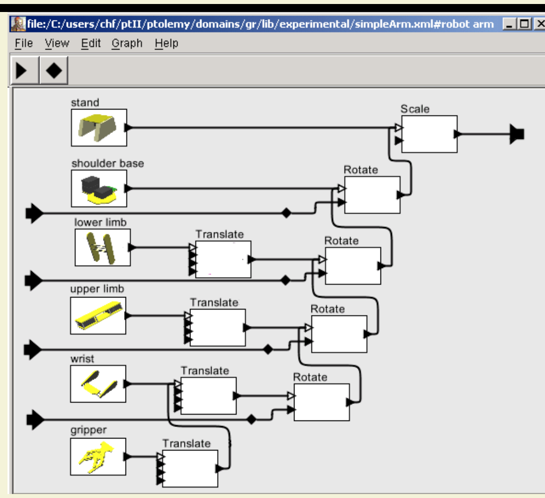
Scene Graphs (cont …)



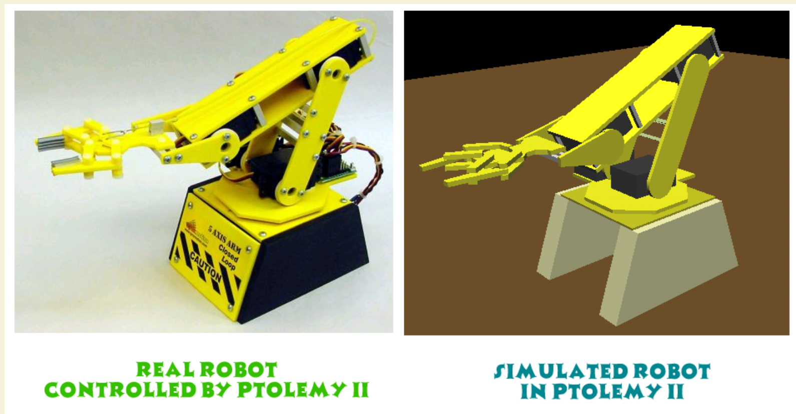
GR Domain



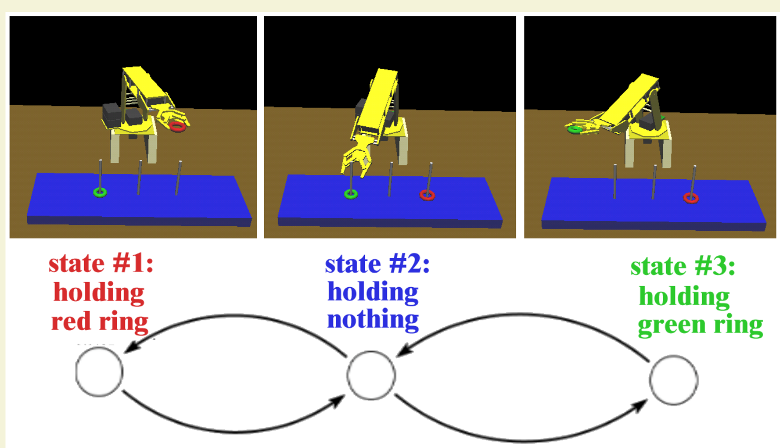
Robot Arm Scene Graph



Robot Arm Simulation



Application of *charts

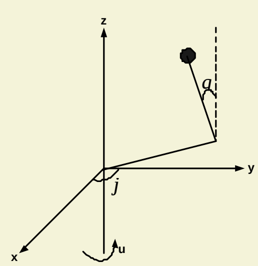


Furuta Pendulum Simulation

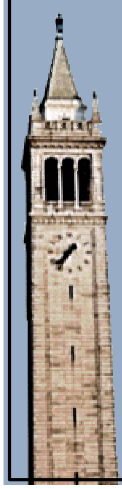
The System

- highly nonlinear
- four states
  - the pendulum angle q,
  - and its velocity $\dot{q}$
  - the arm angle f,
  - and its velocity $\dot{f}$
- the equations
  - u is the input signal
  - $\left(J_p + Ml^2\right)\left(\ddot{q} - \dot{j}^2 \sin q \cos q\right) + Mrl\,\ddot{j}\cos q - gl\left(M + m/2\right)\sin q = 0$

$$Mrl\ddot{q}\cos q - Mrl\dot{q}^2 \sin q + 2\left(J_p + ml^2\right)\dot{q}\dot{j}\sin q \cos q$$
$$+(J + mr^2 + Mr^2 + (Jp + ml^2)\sin^2 q)\ddot{j} = u$$

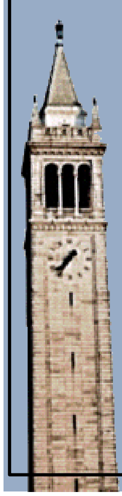


The Controller



- start the pendulum in the downright position
- assume that all signals may be measured
- use one controller to swing it up
  - energy based approach
- use another to catch
  - linear state feedback
- use a third to stabilize it
  - linear state feedback
- implemented using CT+FSM+SDF+GRAPHICS

Linear State Feedback



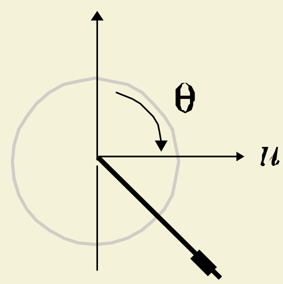
- linearize the system around the top angle

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ a & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ g & 0 & 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ b \\ 0 \\ e \end{bmatrix} u, \quad y = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} x$$

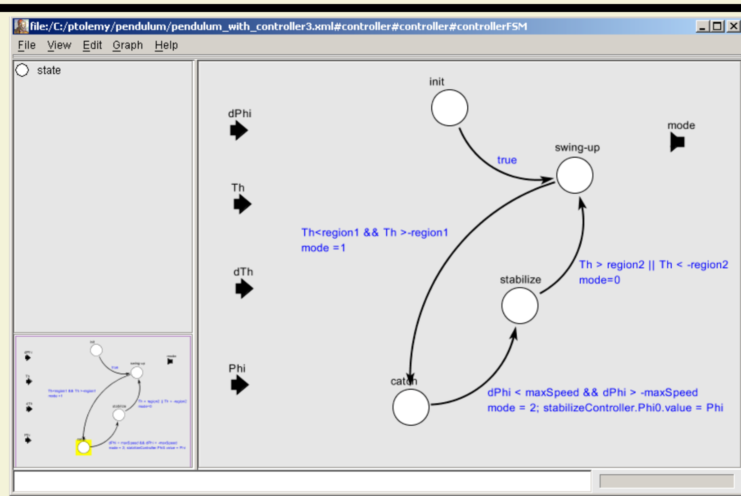
- the control law
  - $u = -\begin{bmatrix} l_1 & l_2 & l_3 & l_4 \end{bmatrix} x$
- two flavors
  - catch
  - stabilize

Swing-up Controller

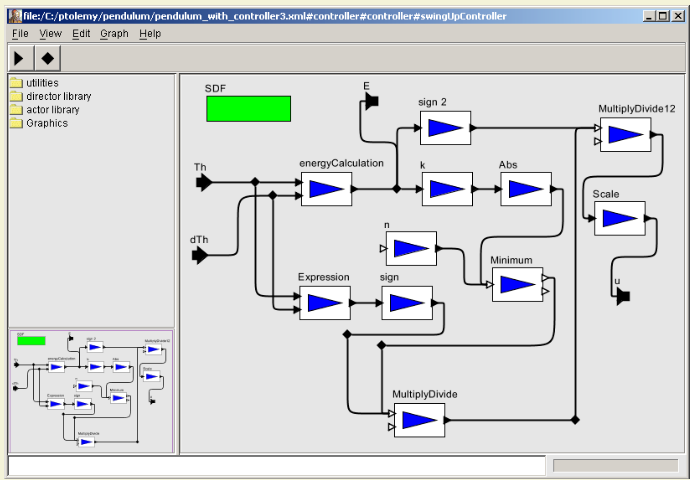
- control the energy of the pendulum
- total energy=kinetic+potential
  - $E = m(\dot{\theta} l)^2 / 2 + mgl(\cos\theta - 1)$
- the control law
  - $u = sat\left(k(E_n - E_o)sign\left(\dot{\theta}\cos\theta\right)\right)$



The Finite State Machine



The Swing-up Controller



Summary

- Framework for visualization of Ptolemy models
- Based on Java 3D
- Easy to animate an existing model
- Future work:
  - Allow to interact with the 3D model
  - Add textures
  - Define semantics for the GR domain