RESEARCH & DESIGN

CONTROL SYSTEM FOR TWO ROBOT ARMS

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OUTLINES

- INTRODUCTION
- THEORETICAL BASIS
- CONTROL SYSTEM
- SIMULATION

INTRODUCTION

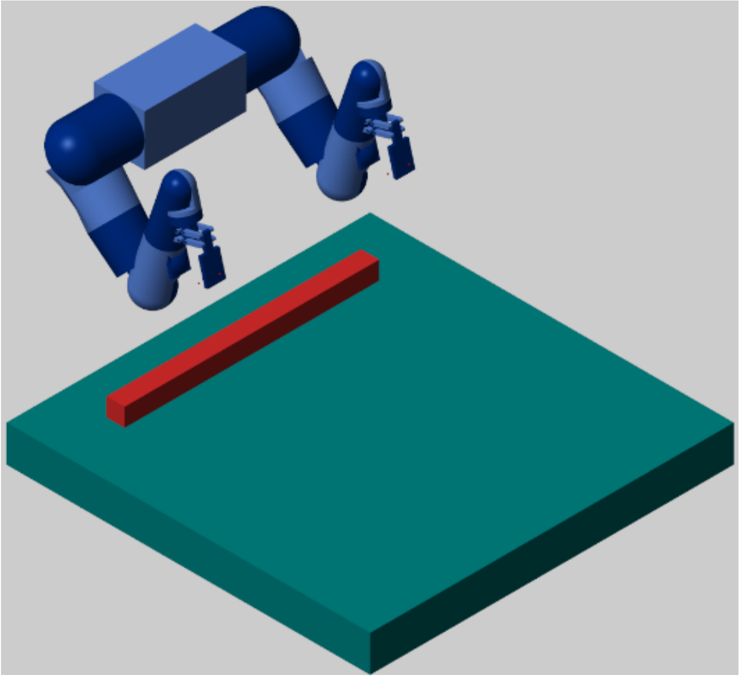
1.5 MILLIONS ROBOT
WOLRDWIDE

DRIVE THE WORLD TOP INDUSTRIES
Japan, Germany, America, ...

PERSONAL INTEREST

PROJECT OVERVIEW

- Cooperation between 2 arms
- Object follow trajectory
- Create 3D models
- Design Control System
- Simulate and examine



THEORETICAL BASIS

- ROBOTICS
- PID CONTROLLER
- FUZZY CONTROL
- DISCRETE EVENT SYSTEM

ROBOTICS

- Kinematics:
  - Forward

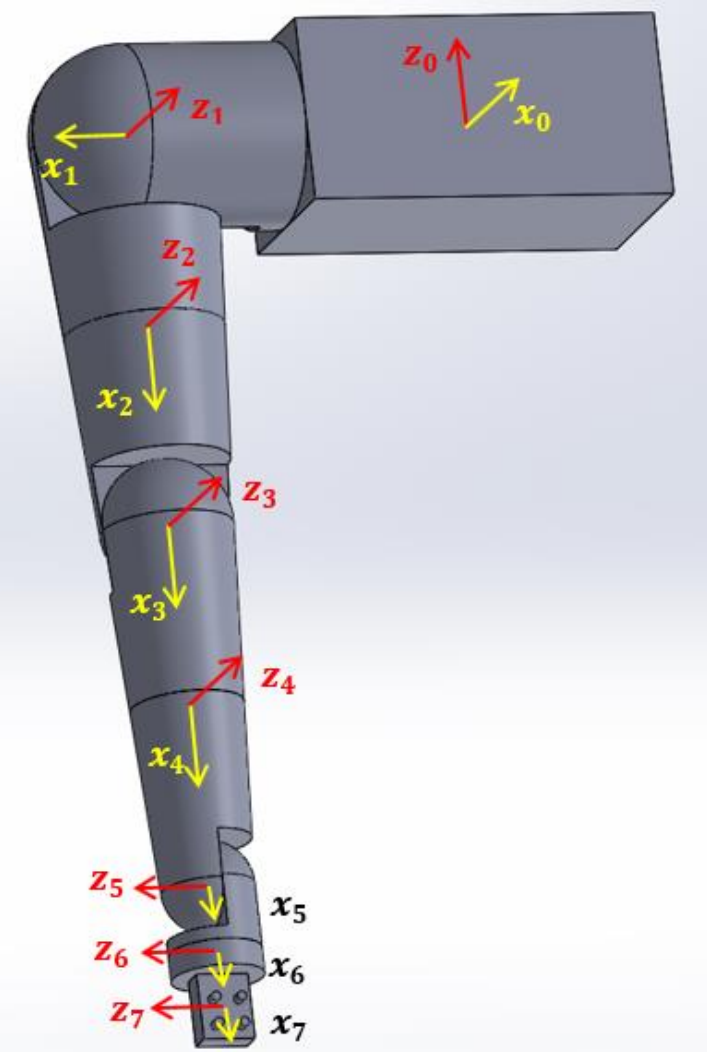
$$A_n^0 = A_1^0 . A_2^1 . A_3^2 . \dots . A_n^{n-1}$$

  - Inverse:

$$A_n^0(x, y, z, \alpha, \beta, \eta) = \begin{bmatrix} c_{11}(q) & c_{12}(q) & c_{13}(q) & x(q) \\ c_{21}(q) & c_{22}(q) & c_{23}(q) & y(q) \\ c_{31}(q) & c_{32}(q) & c_{33}(q) & z(q) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- Dynamics

$$M(q).\ddot{q} + C(q, \dot{q}).\dot{q} + G(q) + Q = \tau$$



ROBOTICS

KINEMATICS VS DYNAMICS

KINEMATICS	DYNAMICS
Easy	Complex
Forwards: always solvable	No absolute accuracy
Inverse: more DOF, more problem, number of solution?	

7 DOF ROBOT ARM?

With the help of computer?

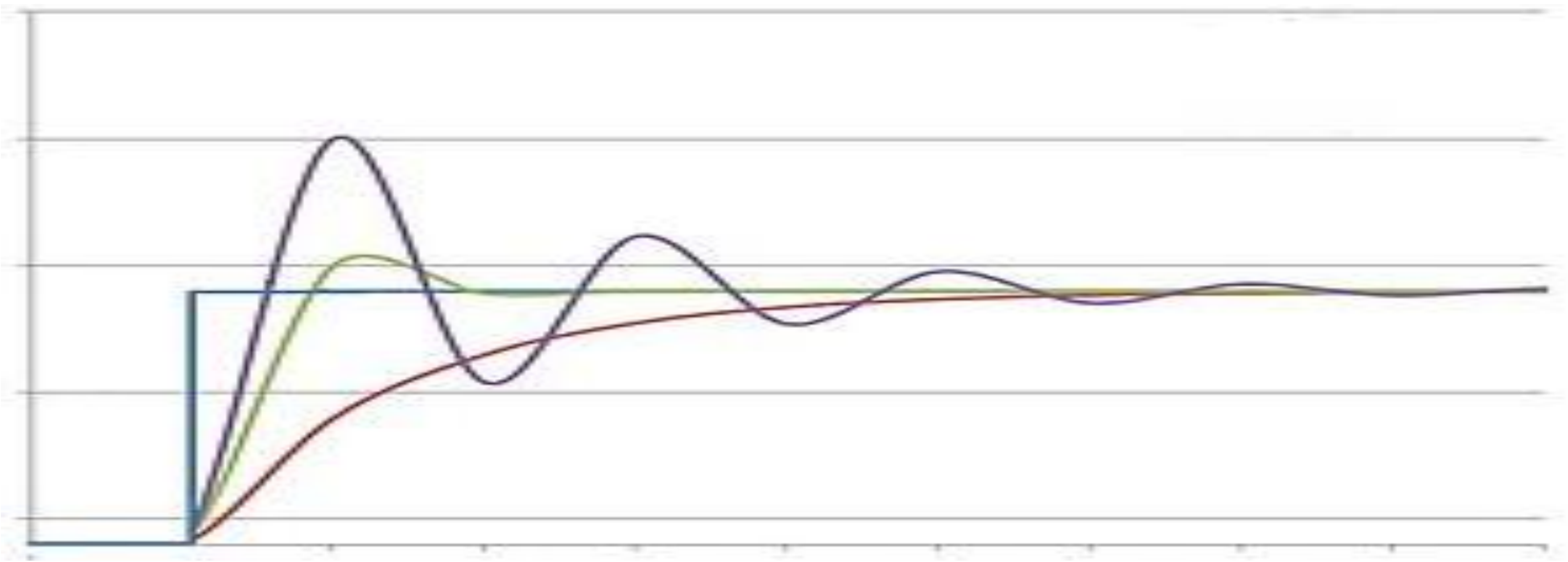
PID CONTROLLER

- The most applied control method
- Easy, simple, yet EFFECTIVE

$$u(t) = k_p\left[e(t) + \frac{t}{T_1}\int_0^t e(\tau)d\tau + T_D.\frac{de(t)}{dt}\right]$$

PID CONTROLLER

- Control quality depends on parameters
- Stability?



FUZZY CONTROL

- Inspire from the brain's way of perceiving
- Fuzzy sets, membership functions, fuzzy models, rules, defuzzification…

FUZZY CONTROL

- Simple to understand
- Depend on the experience of designers
- Highly integrable with other methods (PID controller, sliding mode control, adaptive, neural network...)

DISCRETE EVENT SYSTEM

- New class of dynamic system with event-driven transition, discrete space
- Automata definition:

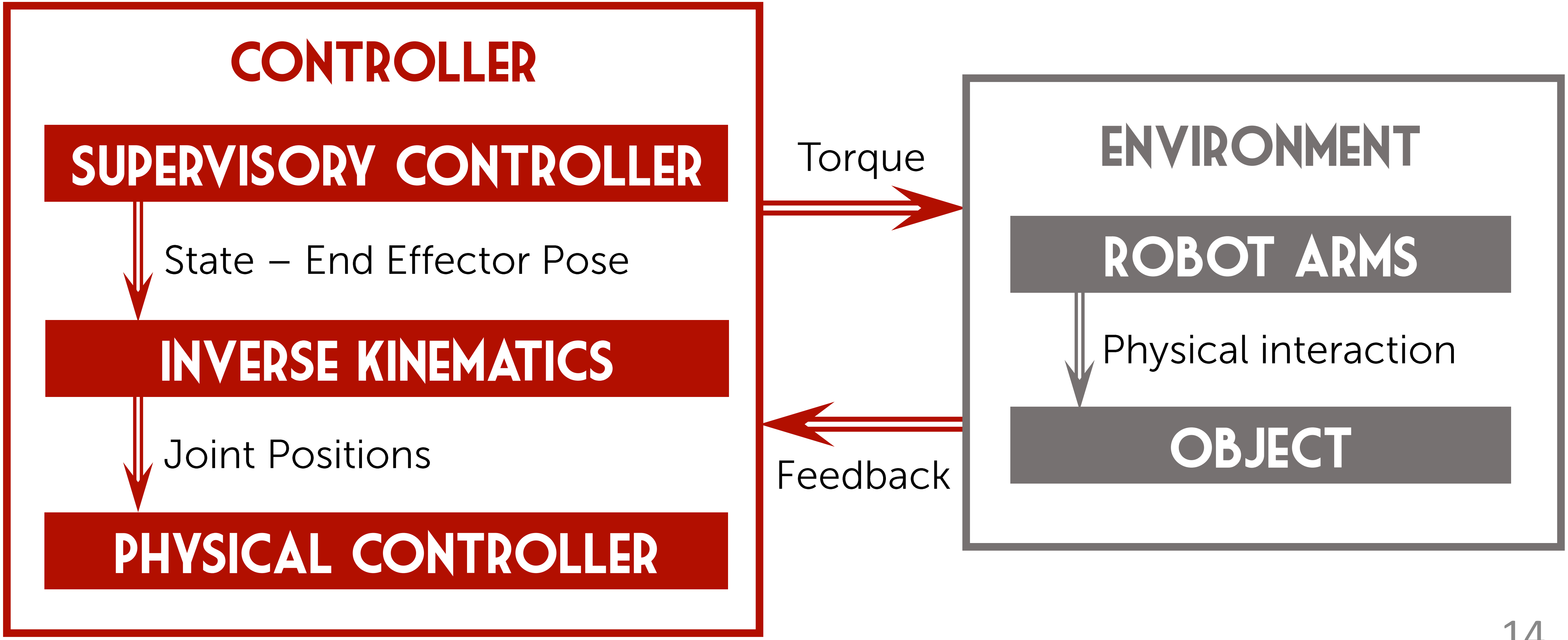
$$G = \{X, E, f, \Gamma, x_0, X_m\}$$

- Properties: safety, blocking, deterministic…

DISCRETE EVENT SYSTEM

- Application in service sectors, transport systems, tele-communication, ...
- Supervisory control
  - Robot: variety of conditions...

HIERARCHICAL STRUCTURE

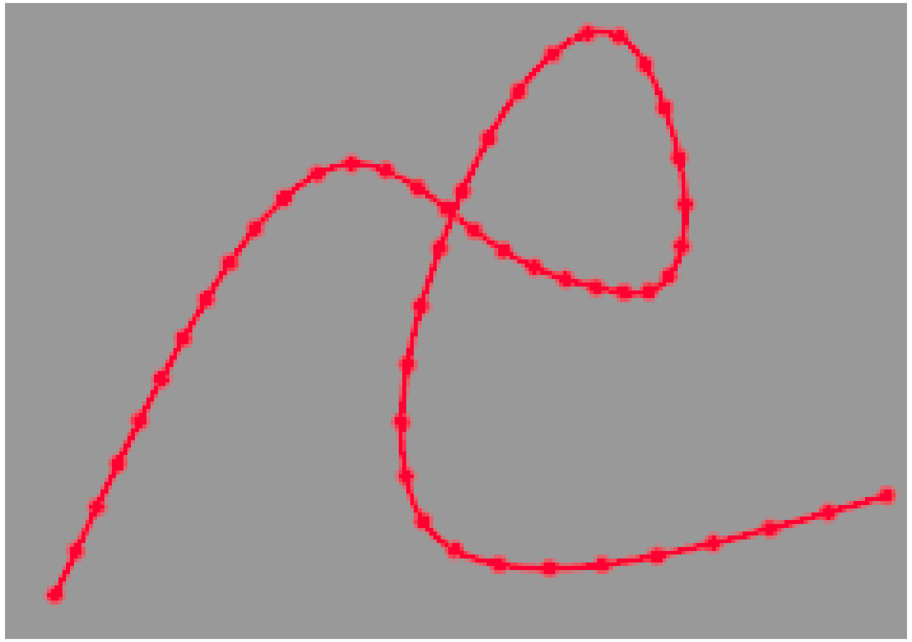


SUPERVISORY CONTROLLER

Idea of trajectory tracking:

NOT
TIME TRACKING

BUT
STATE TRACKING
ERROR TOLERANCE



SUPERVISORY CONTROLLER

Automata model

- Inputs

$$U \coloneqq \{JointPose\ R\&L, ObjectPosition, EEPose\ R\&L, GripForceR\&L, ObjectAngle\}$$

- Outputs

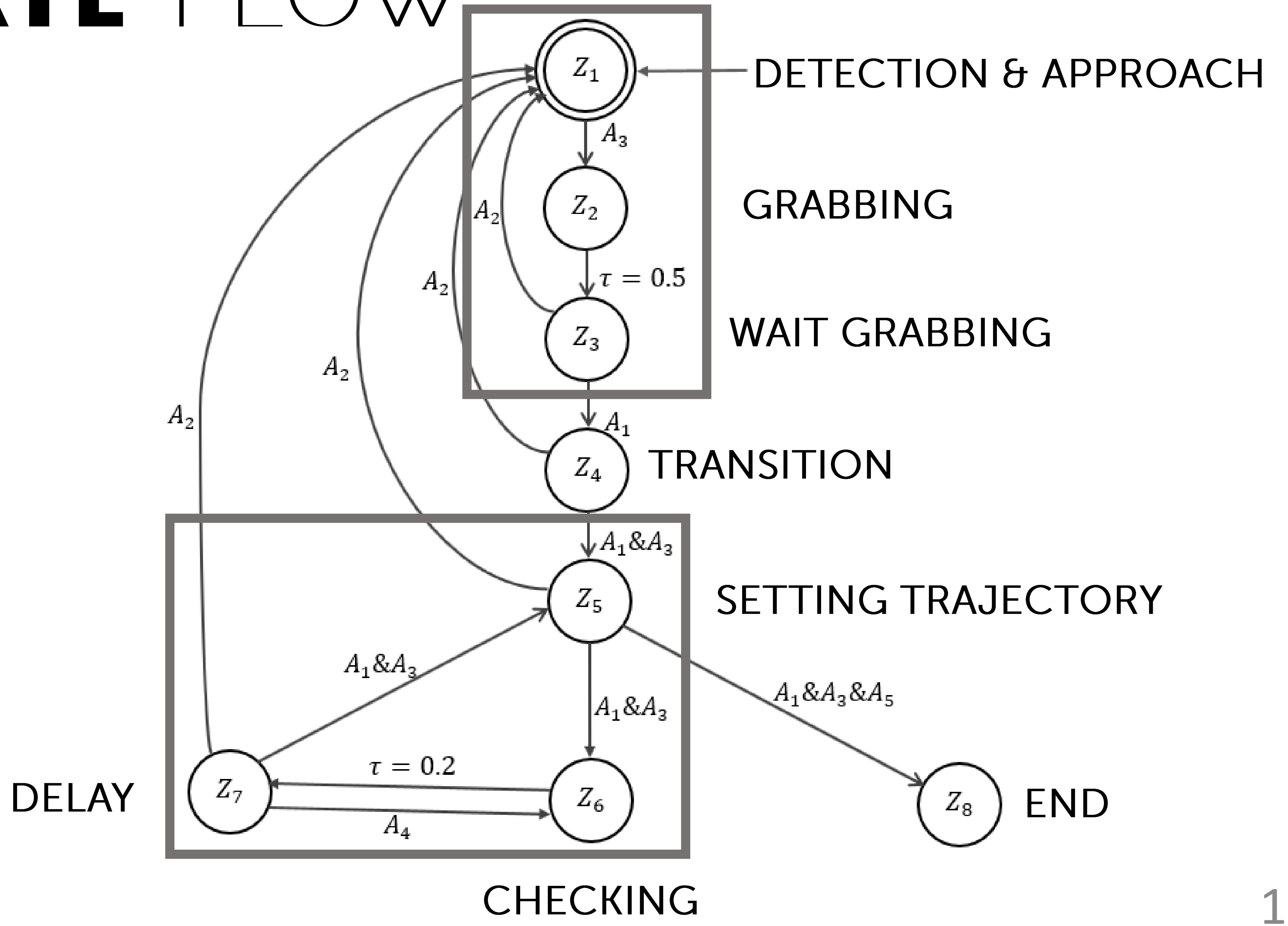
$$Y \coloneqq \{DesiredJointStates\ R\&L, GripCommand\}$$

- States

- Events

A_1: Object detected, A_2:No object, A_3: Pose satisfied, A_4: Pose unsatisfied, A_5: End.

STATE FLOW



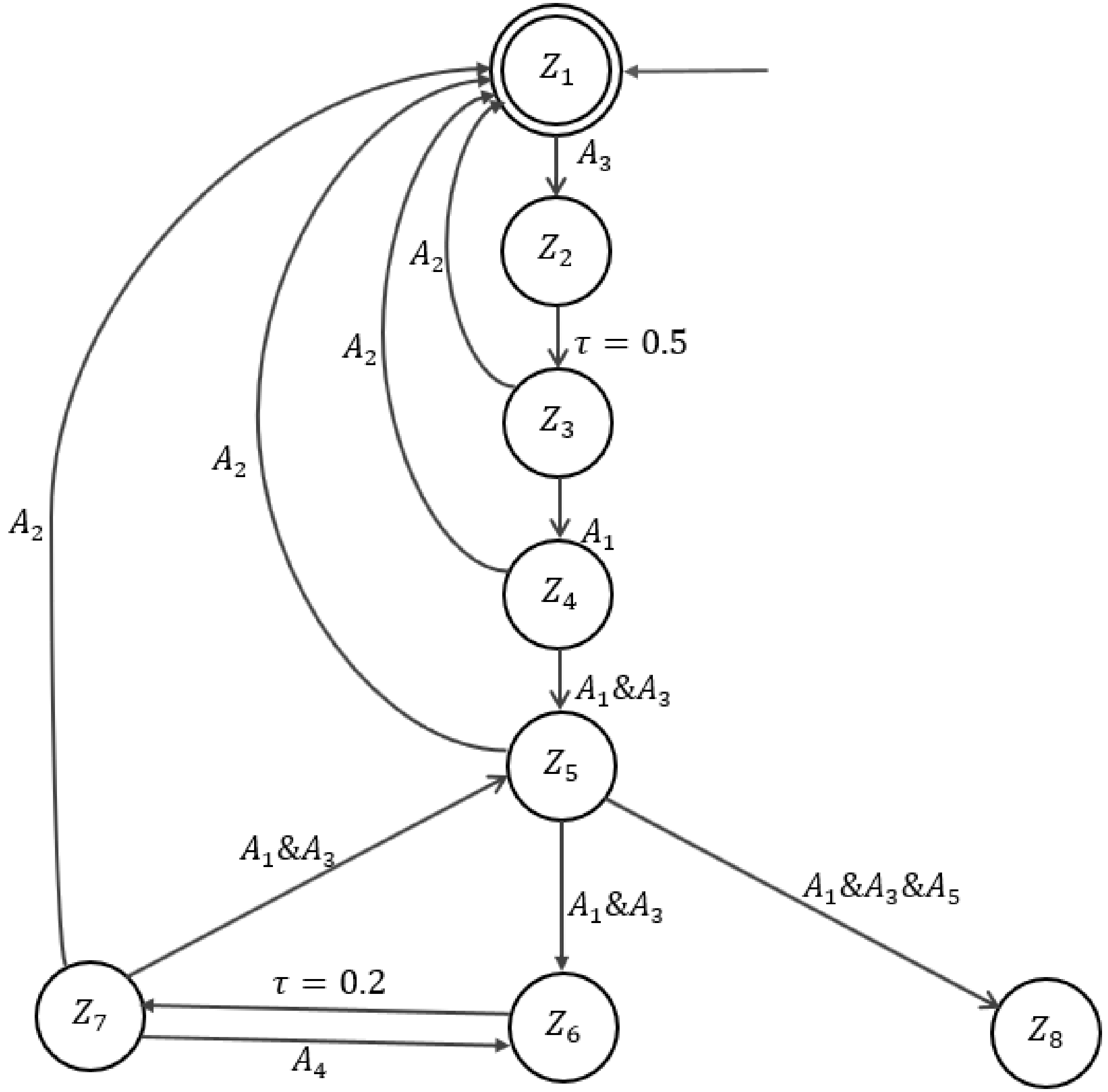
Z_1
DETECTION & APPROACH
A_3
Z_2
GRABBING
A_2
$\tau = 0.5$
A_2
Z_3
WAIT GRABBING
A_2
A_2
A_1
Z_4
TRANSITION
$A_1\&A_3$
Z_5
SETTING TRAJECTORY
$A_1\&A_3$
$A_1\&A_3\&A_5$
$A_1\&A_3$
$\tau = 0.2$
DELAY
Z_7
Z_6
Z_8
END
A_4
CHECKING

SUPERVISORY CONTROLLER

Properties:

- Reachability
- Dead-end: Z_1, Z_5

...



INVERSE KINEMATICS

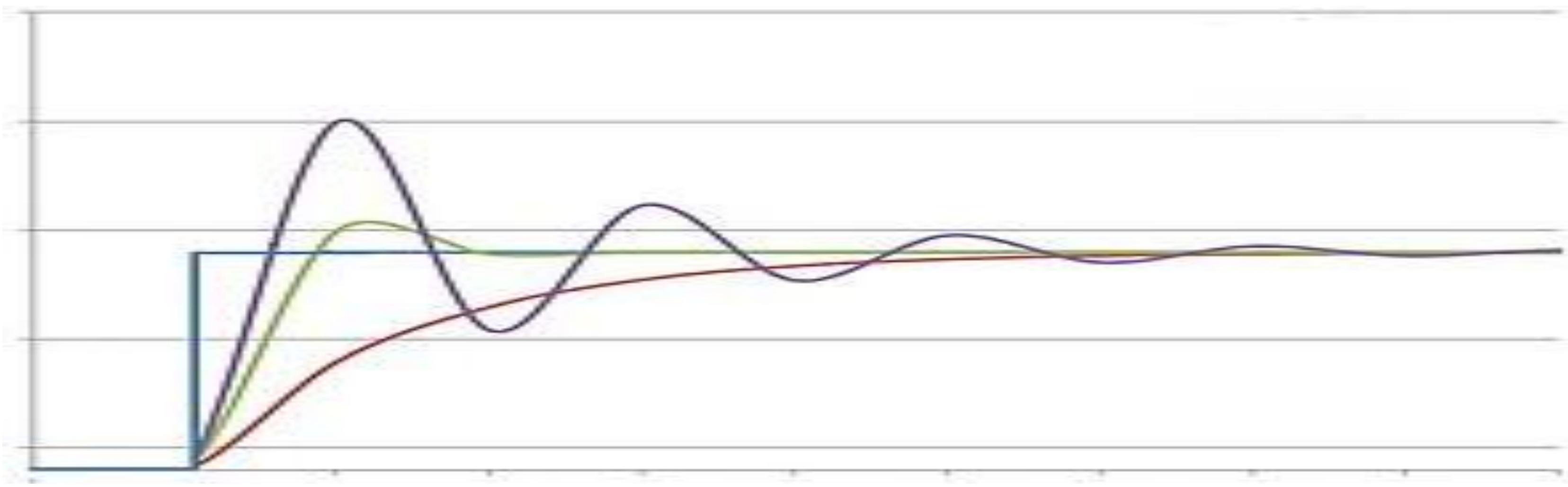
Robotics Toolbox (MATLAB)

- URDF models
- Generalized Inverse Kinematics: for constraints
- BFGS gradient projection algorithm: for greater position error

PHYSICAL CONTROLLER

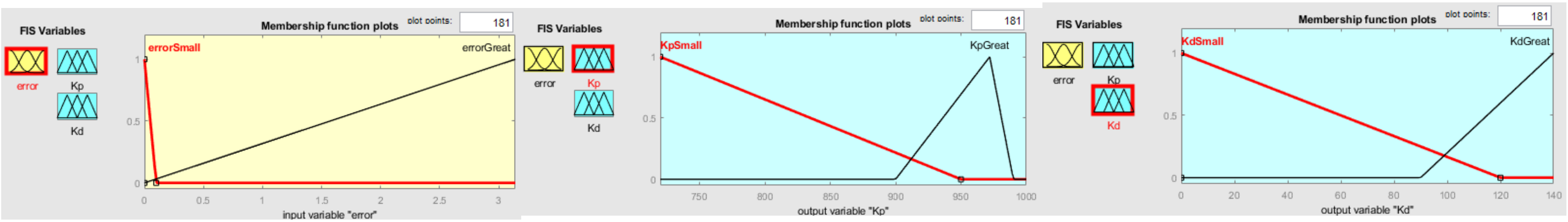
PID alone leads to undesired control quality

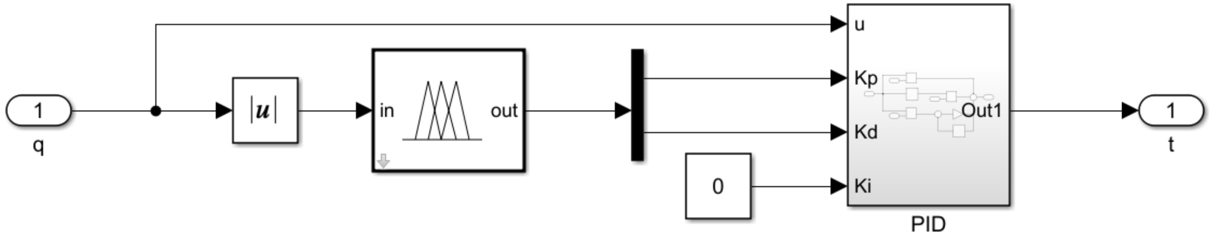
- Fluctuated
- Unstable joint positions
- Tracking time



PHYSICAL CONTROLLER

IF error is $errorSmall$ THEN Kp is $KpGreat$ and Kd is $KdGreat$.
IF error is $errorGreat$ THEN Kp is $KpSmall$ and Kd is $KdSmall$.



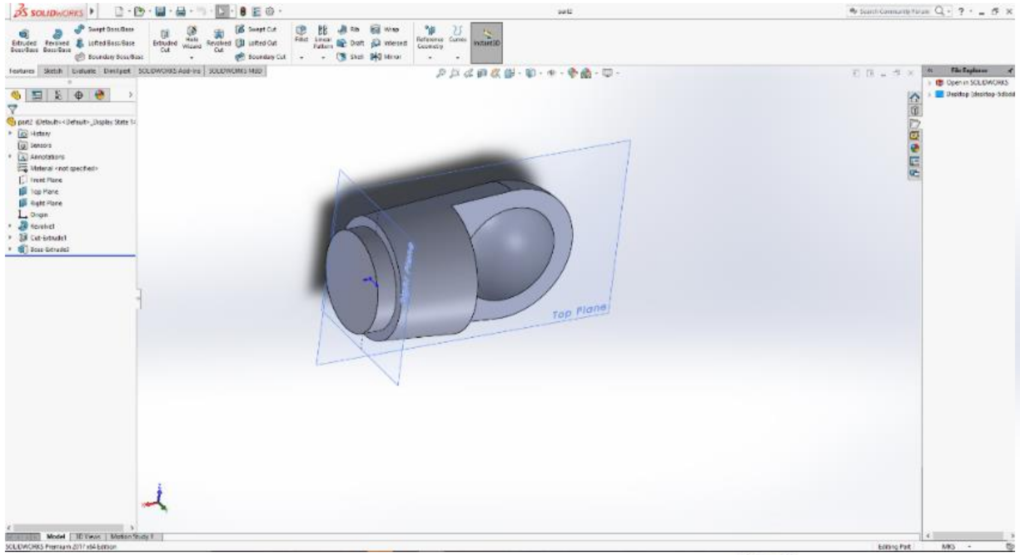


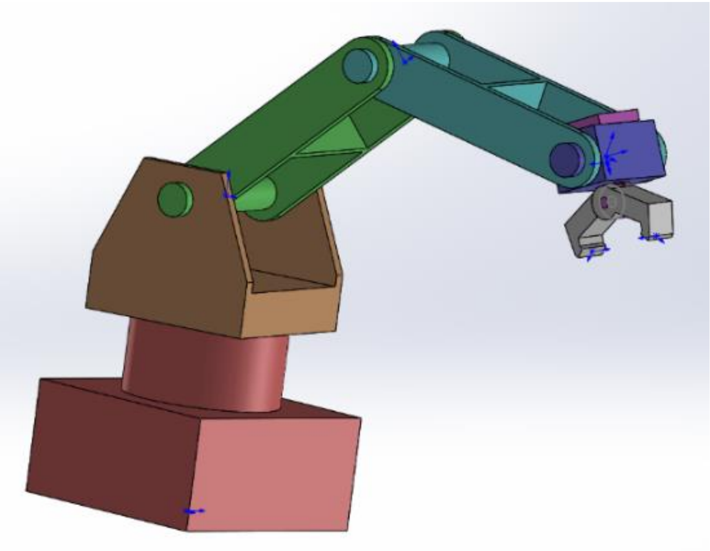
SIMULATION

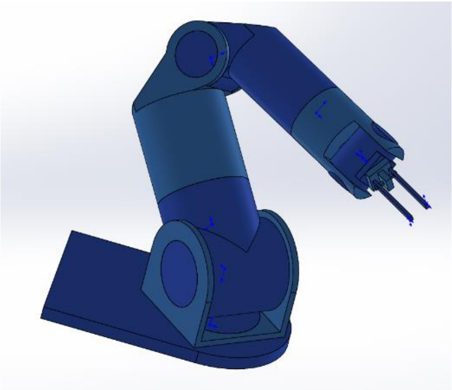
3D MODELS

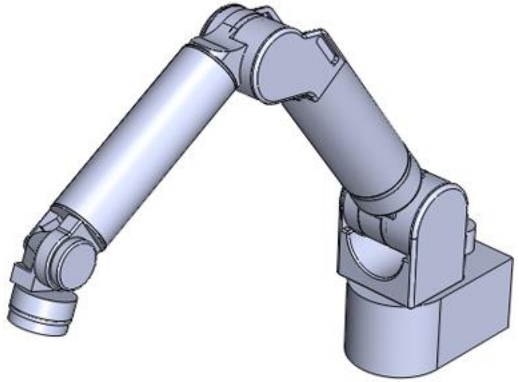
RESULTS

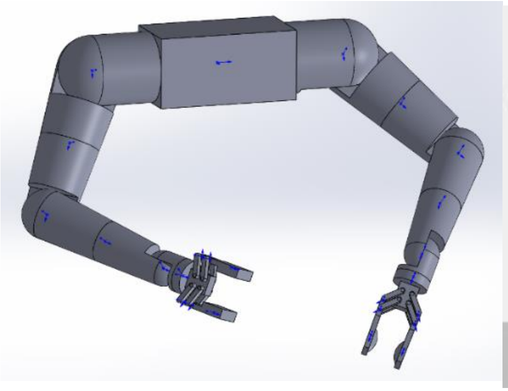
SOLIDWORKS



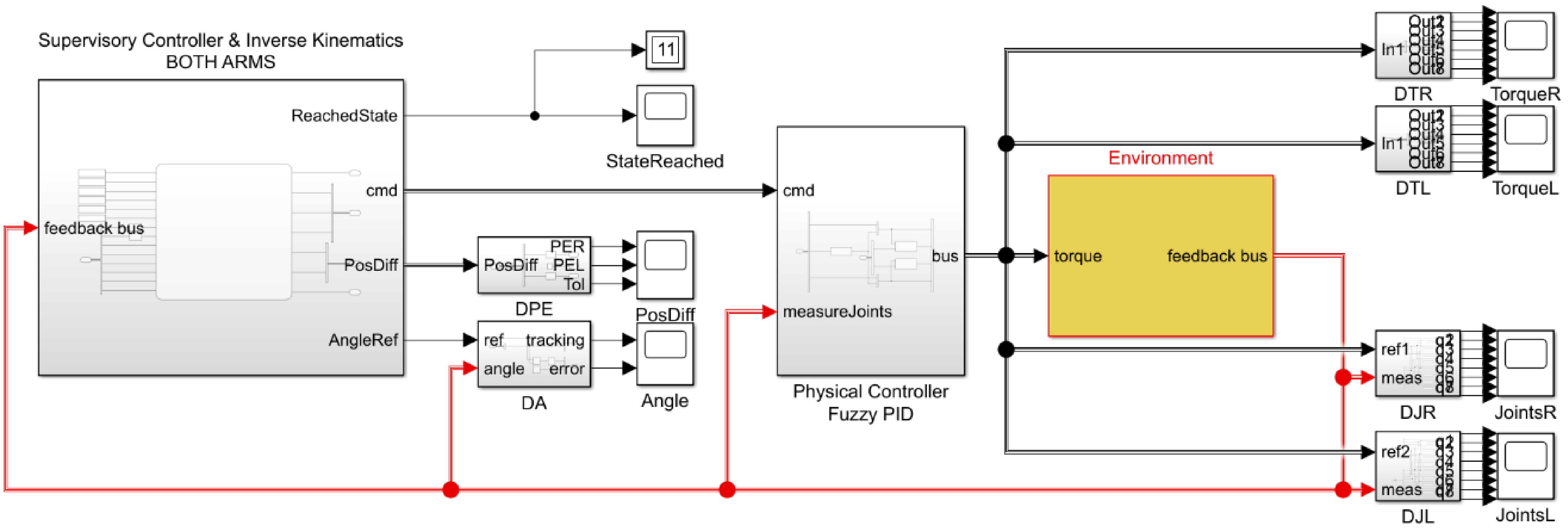








SIMULATION


Supervisory Controller & Inverse Kinematics
BOTH ARMS
ReachedState
cmd
feedback bus
PosDiff
AngleRef
11
StateReached
PosDiff
PER
PEL
Tol
DPE
PosDiff
ref
tracking
angle
error
DA
Angle
cmd
bus
measureJoints
Physical Controller
Fuzzy PID
Environment
torque
feedback bus
In1
DTR
TorqueR
In1
DTL
TorqueL
ref1
meas
DJR
JointsR
ref2
meas
DJL
JointsL

CONCLUSION

ACCOMPLISHED:

- 3D Simulation
- All parts of hierarchical control system perform as expected

UNACCOMPLISHED:

- System identification (neural network...)

FURTHER RESEARCH

REAL PHYSICAL MODELS with **MICROCONTROLLER**

SYSTEM **IDENTIFICATION**

More **COMPLEX** processes, control methods, ...

THANK YOU

DISCUSSION