Dynamic modelling of multi-physical domain system by bond graph approach and its control using flatness based controller with MATLAB Simulink

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Need of reliable modelling and simulation tool for multi domain physical system

Development of a mathematical model for Mobile robot using Bond graph technique

Development of Simulink environment for multi domain system

Design of the bond graph model of the Mobile robot using MATLAB Simulink

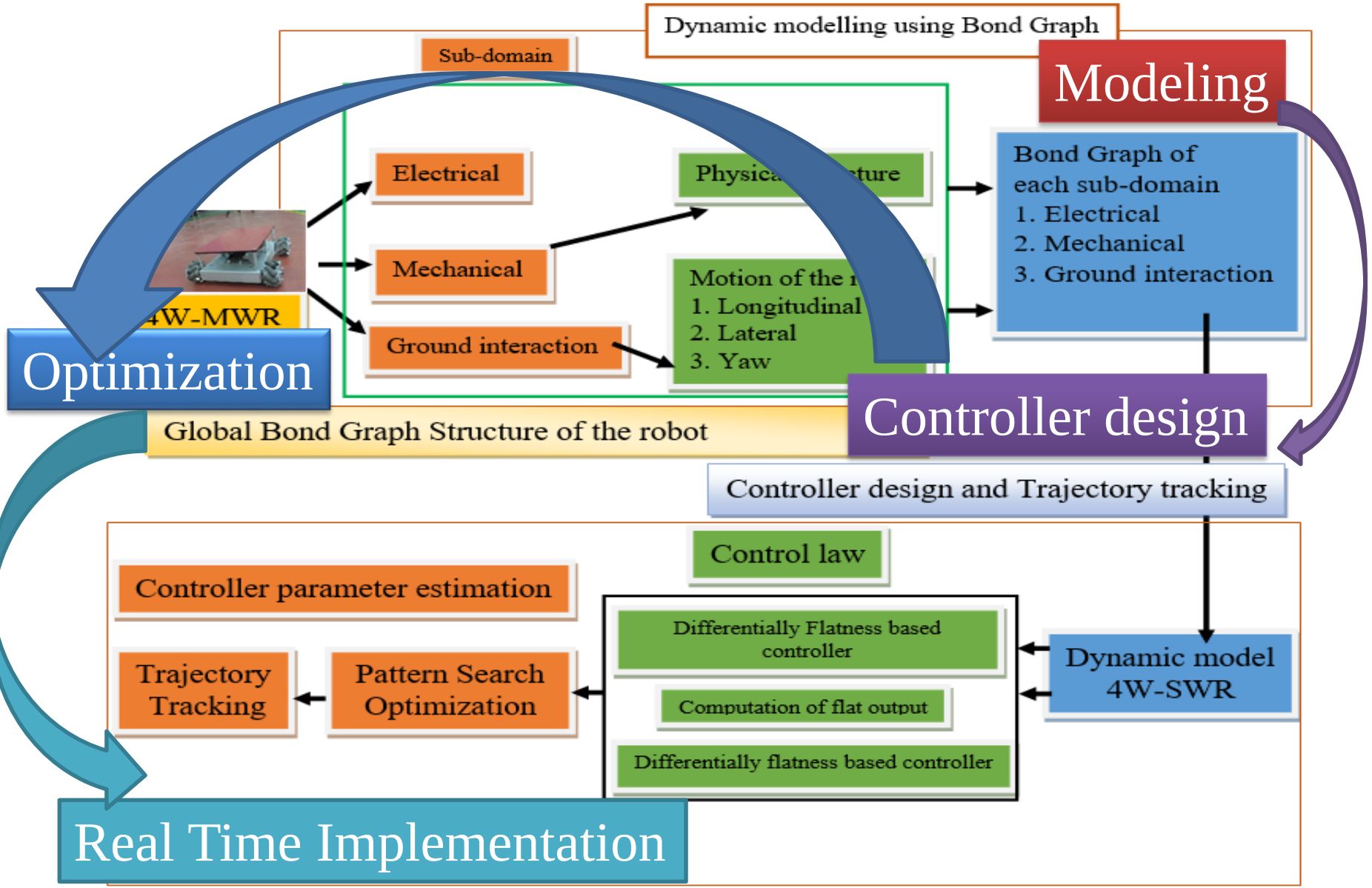
Controller design to achieve desired task for multi domain system

Design of a Flatness based controller to achieve desired trajectory

Real Time and hardware implementation

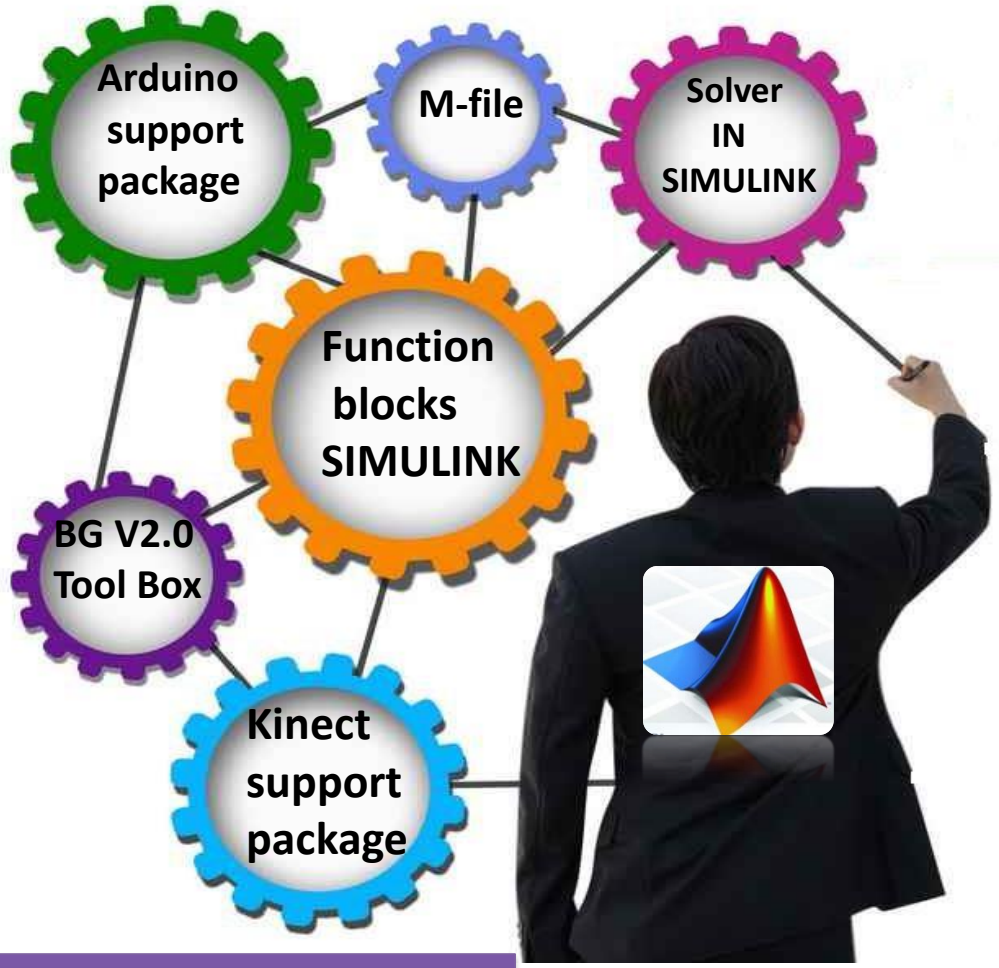
Real time implementation of the proposed Methodology using MATLAB hardware support package

Approach used to solve the problem

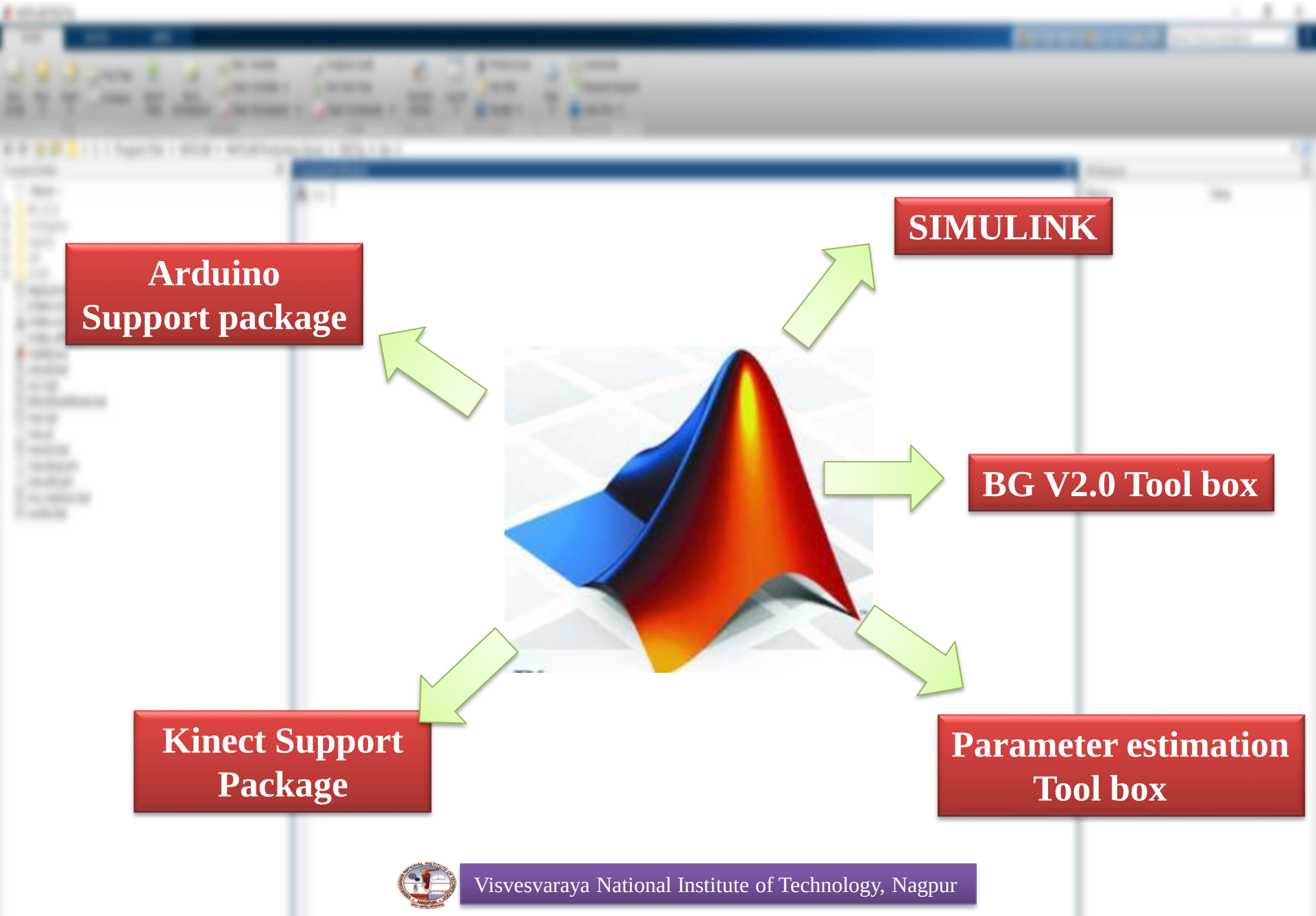


Modelling Challenges & Solutions With MATLAB/SIMULINK

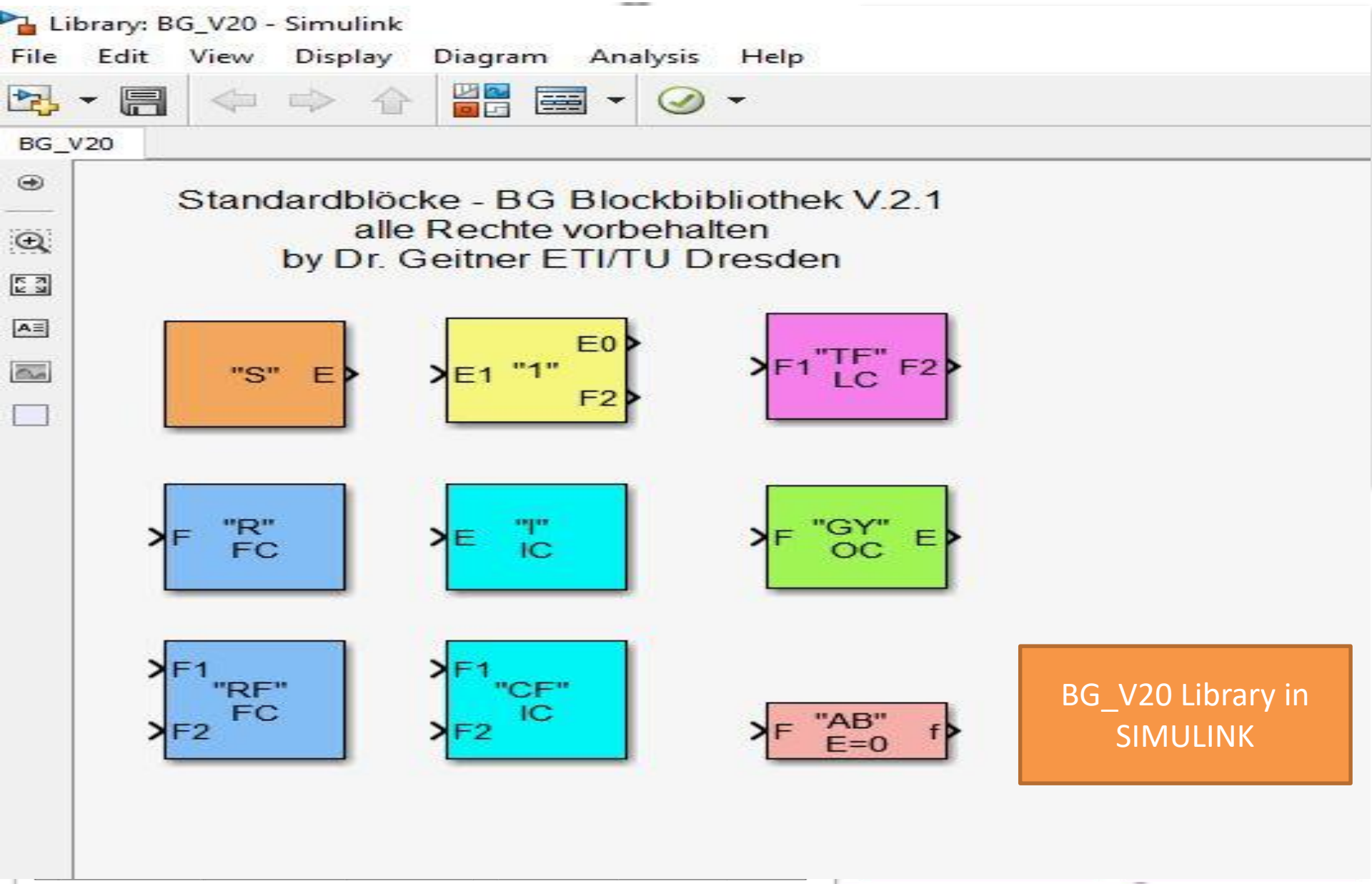
- Dynamic Modelling using Bond Graph
- Non-Linear controller model
- Solving Second order non linear Equations
- Feedback data collection
- Real Time Hardware Implementation



Modelling Tool Used

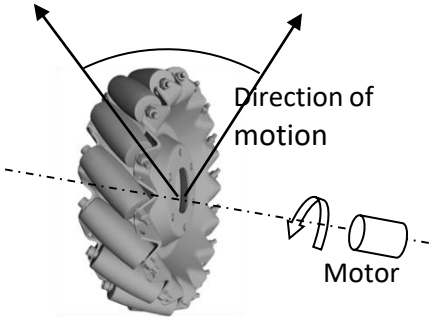


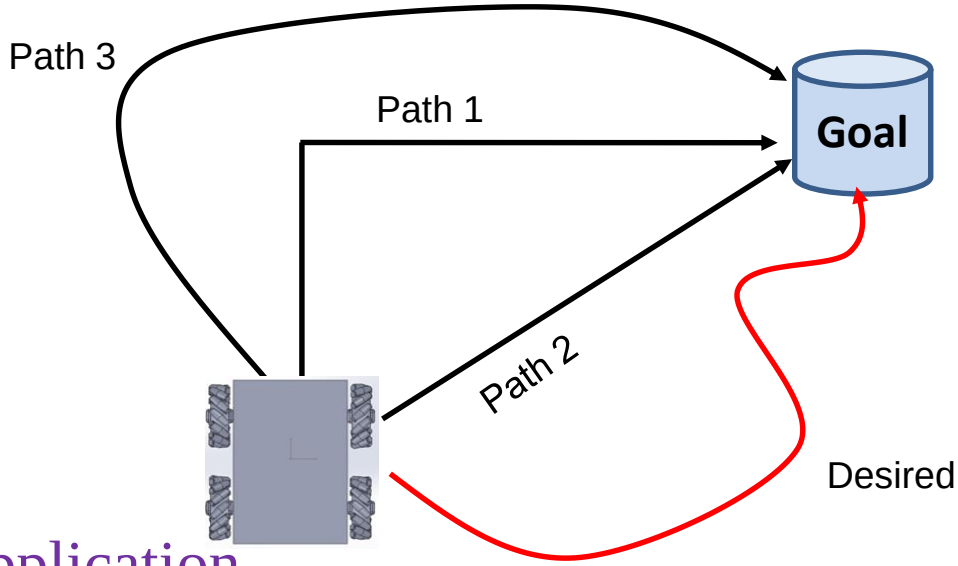
Bond Graph



BG_V20 Library in SIMULINK

Four wheel omnidirectional mobile robot (FWOMR)





(FWOMR)

Application

Warehouse

Wheel chair

Omni move lifter

Home Purpose Robots

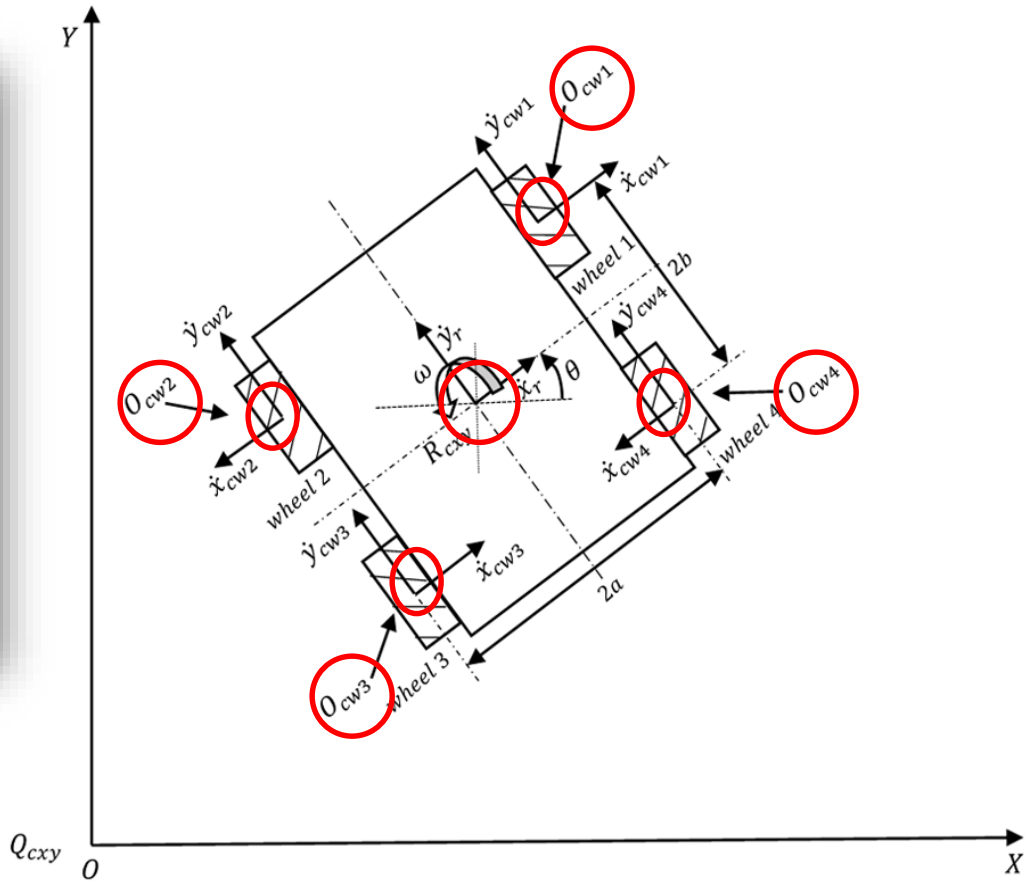
Kinematic modelling of the robot

$$\begin{bmatrix} \dot{x}_r \\ \dot{y}_r \\ \dot{\theta} \end{bmatrix} = \mathrm{J} \begin{bmatrix} \dot{\theta}_{cw1} \\ \dot{\theta}_{cw2} \\ \dot{\theta}_{cw3} \\ \dot{\theta}_{cw4} \end{bmatrix}$$

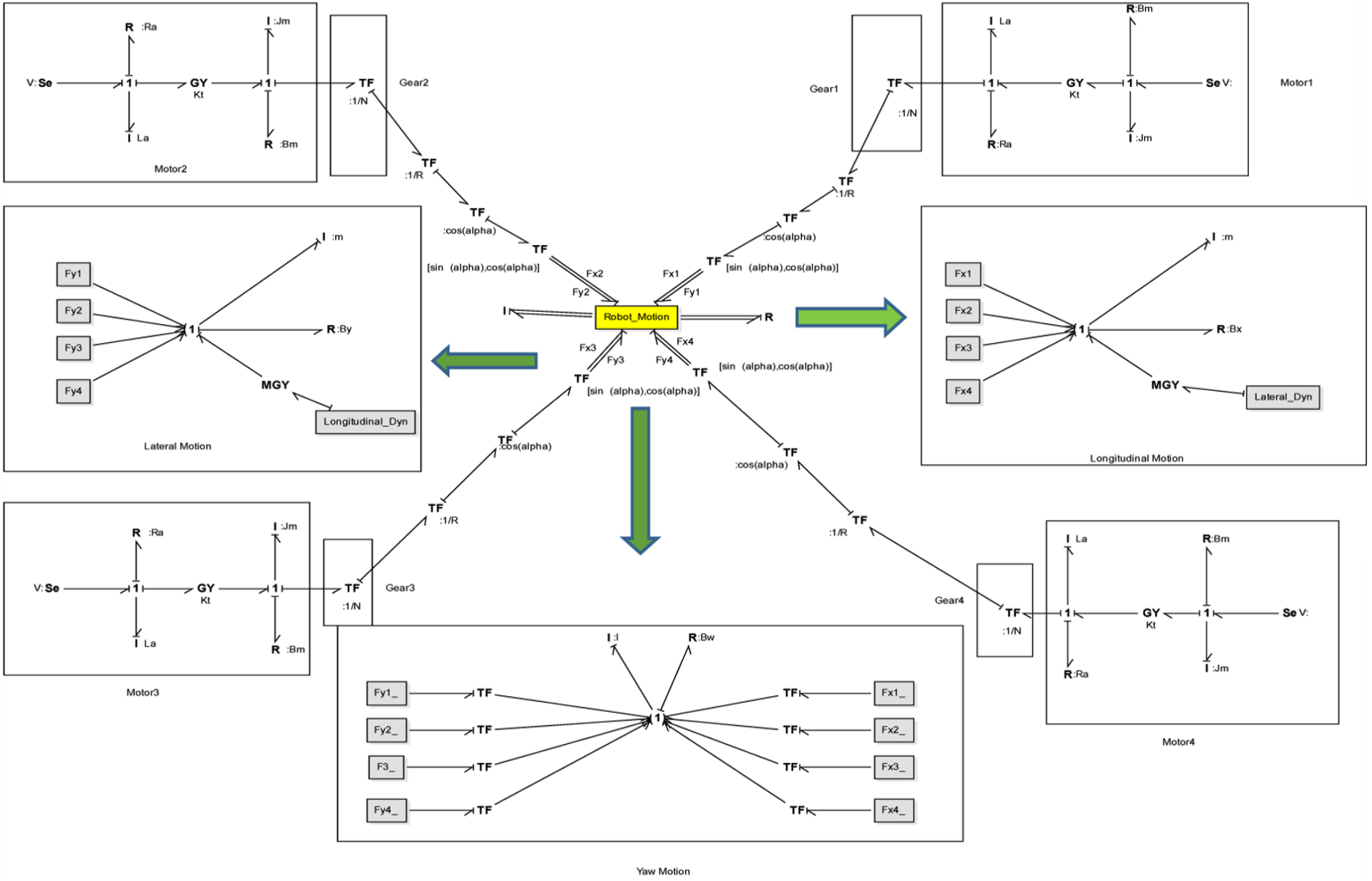
where,

$$J = \frac{R}{4} \begin{bmatrix} -1 & 1 & -1 & 1 \\ 1 & 1 & 1 & 1 \\ \frac{1}{a+b} & -\frac{1}{a+b} & -\frac{1}{a+b} & \frac{1}{a+b} \end{bmatrix}$$

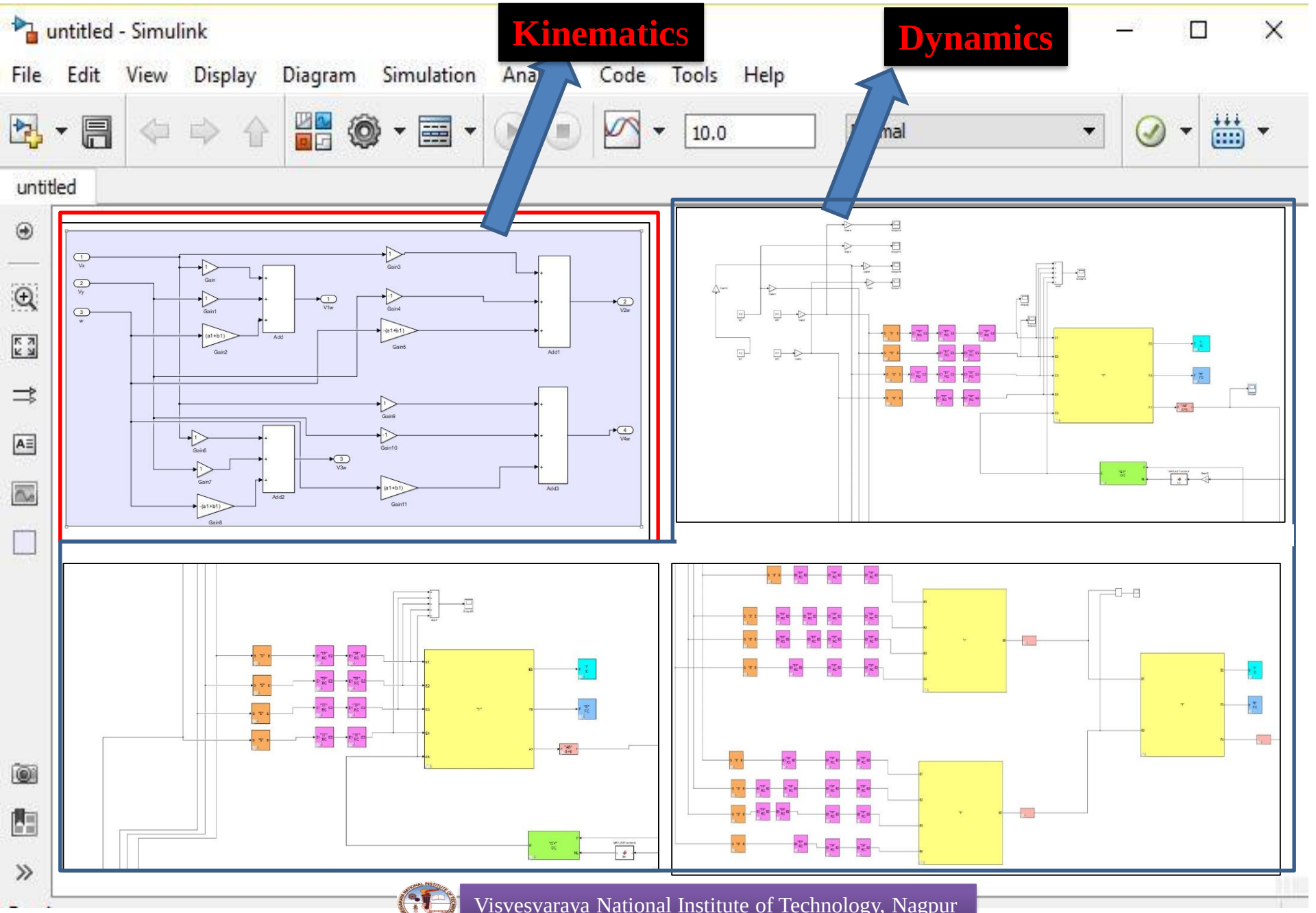
$$\begin{bmatrix} \dot{x}_q \\ \dot{y}_q \\ \dot{\theta}_q \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x}_r \\ \dot{y}_r \\ \dot{\theta}_r \end{bmatrix}$$



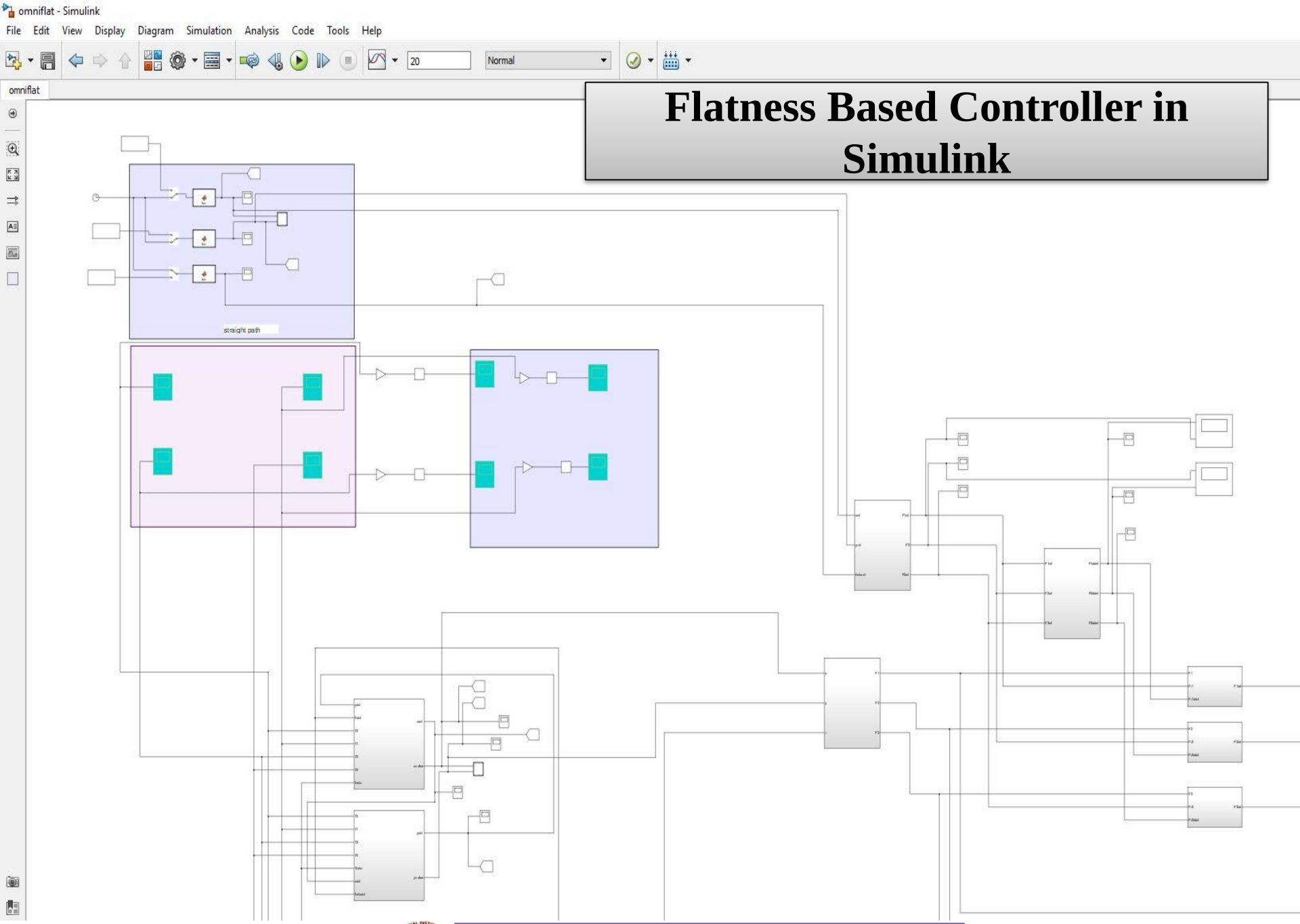
Dynamic modelling using Bond graph of the robot



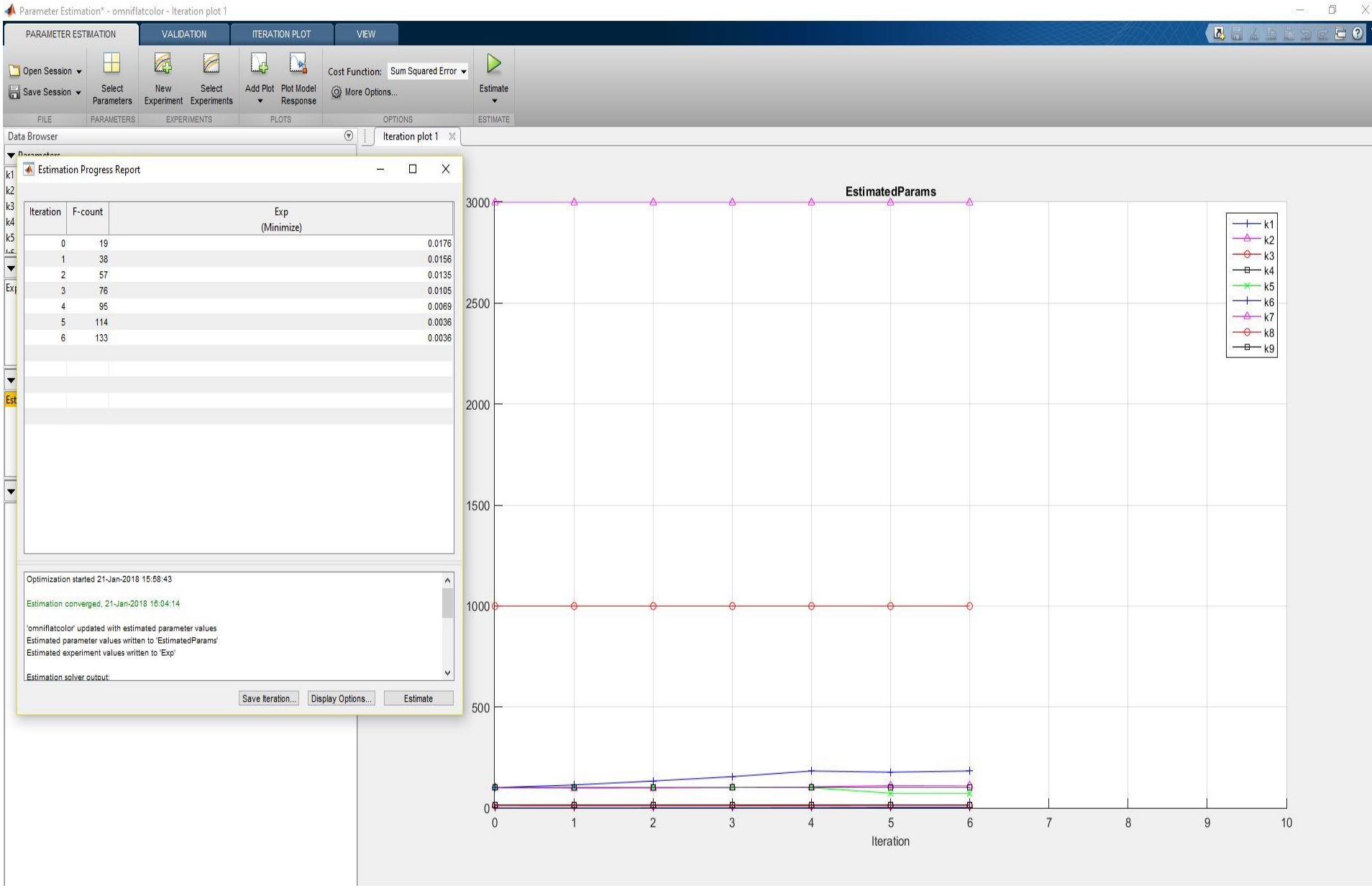
Kinematic and Dynamic Model Using Simulink



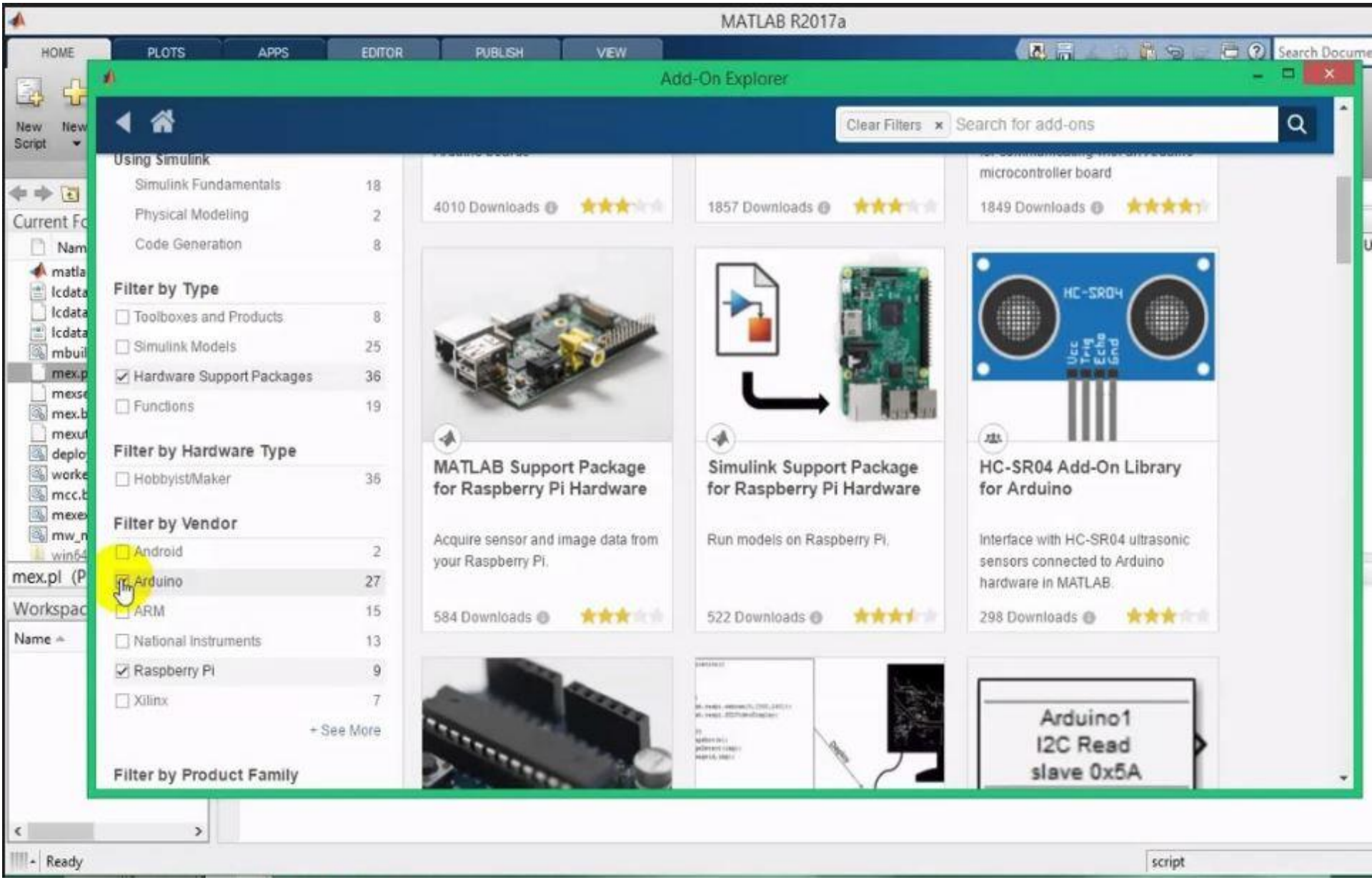
Flatness Based Controller in Simulink



Parameter Estimation toolbox For optimized controller parameter

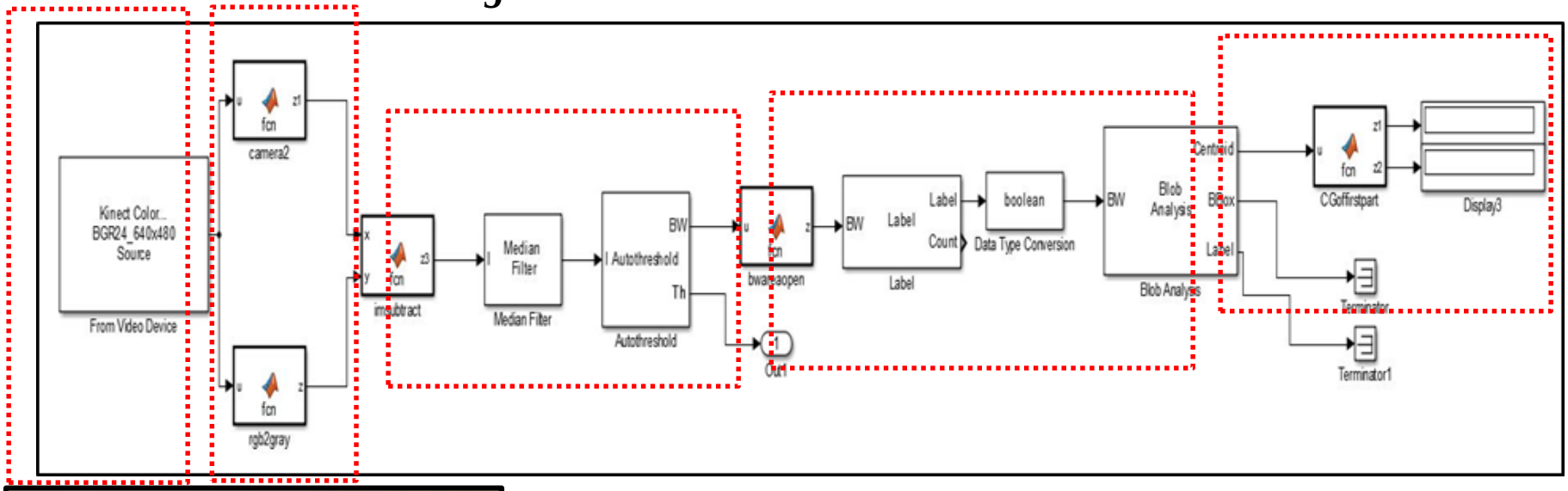


Real Time Implementation of the proposed Scheme



Real Time Implementation of the proposed Scheme

Feedback data collection using Kinect sensor



Experimental Environment

Computed control input is send from SIMULINK to Arduino board

Dynamic model and control BG+FBC

Reference Trajectory (In form of flat output)

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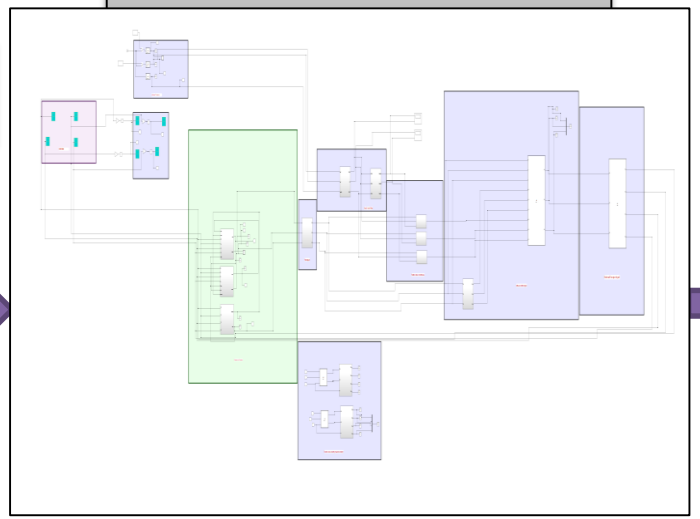
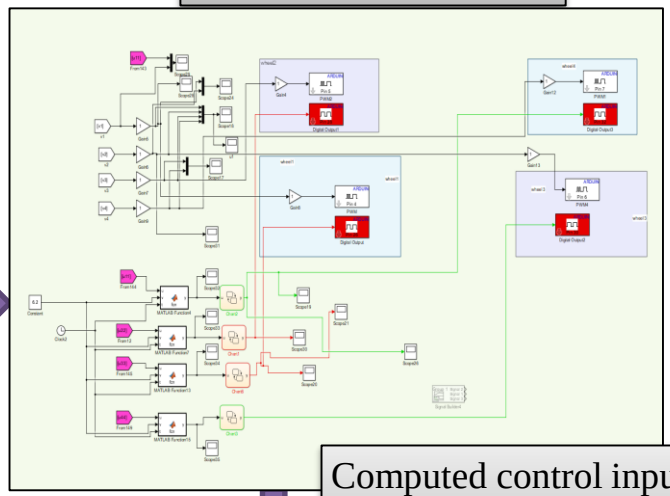
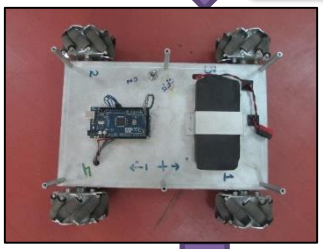
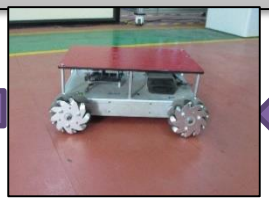




Computed control input To robot

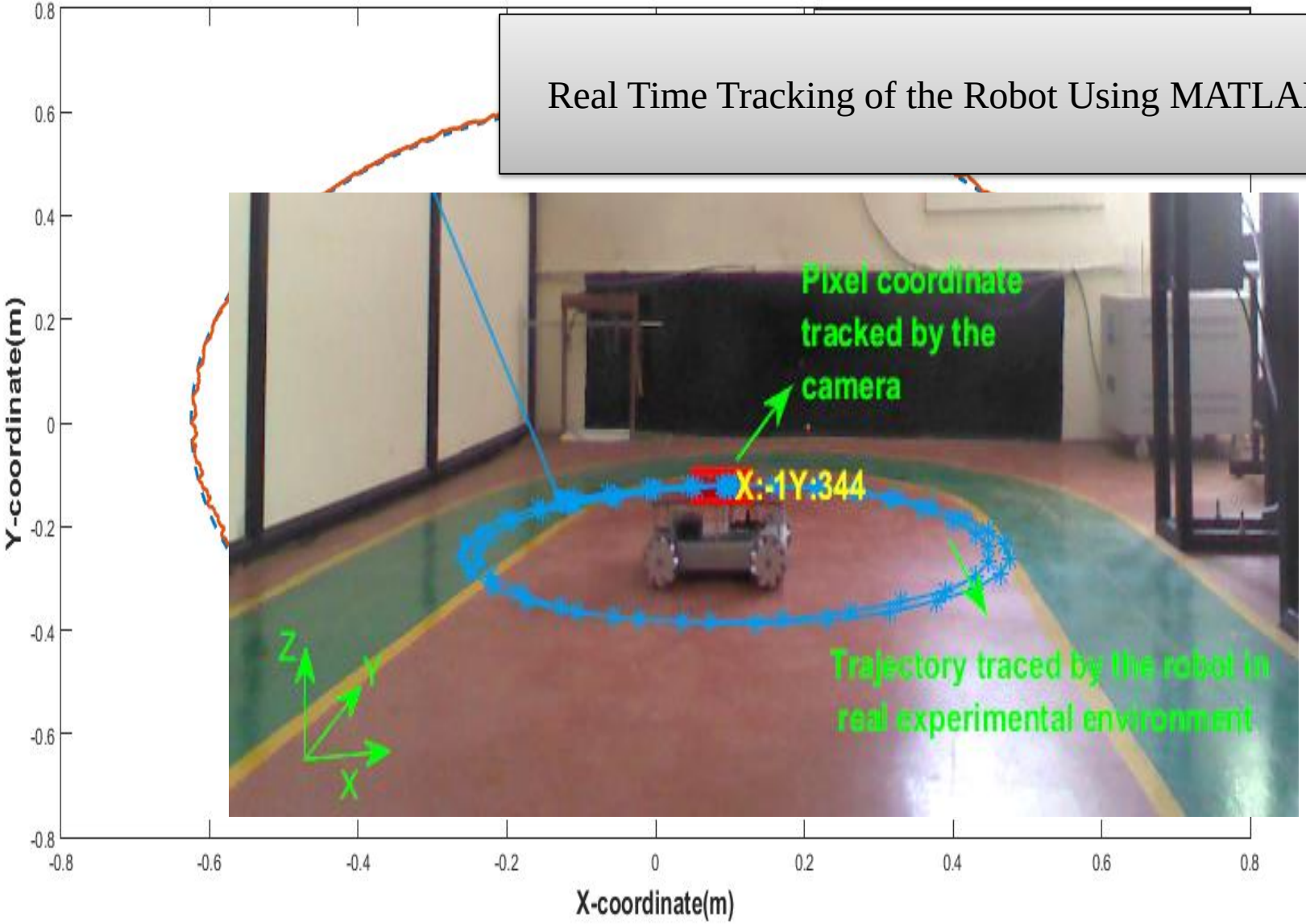


Robot performance in the Experimental Environment



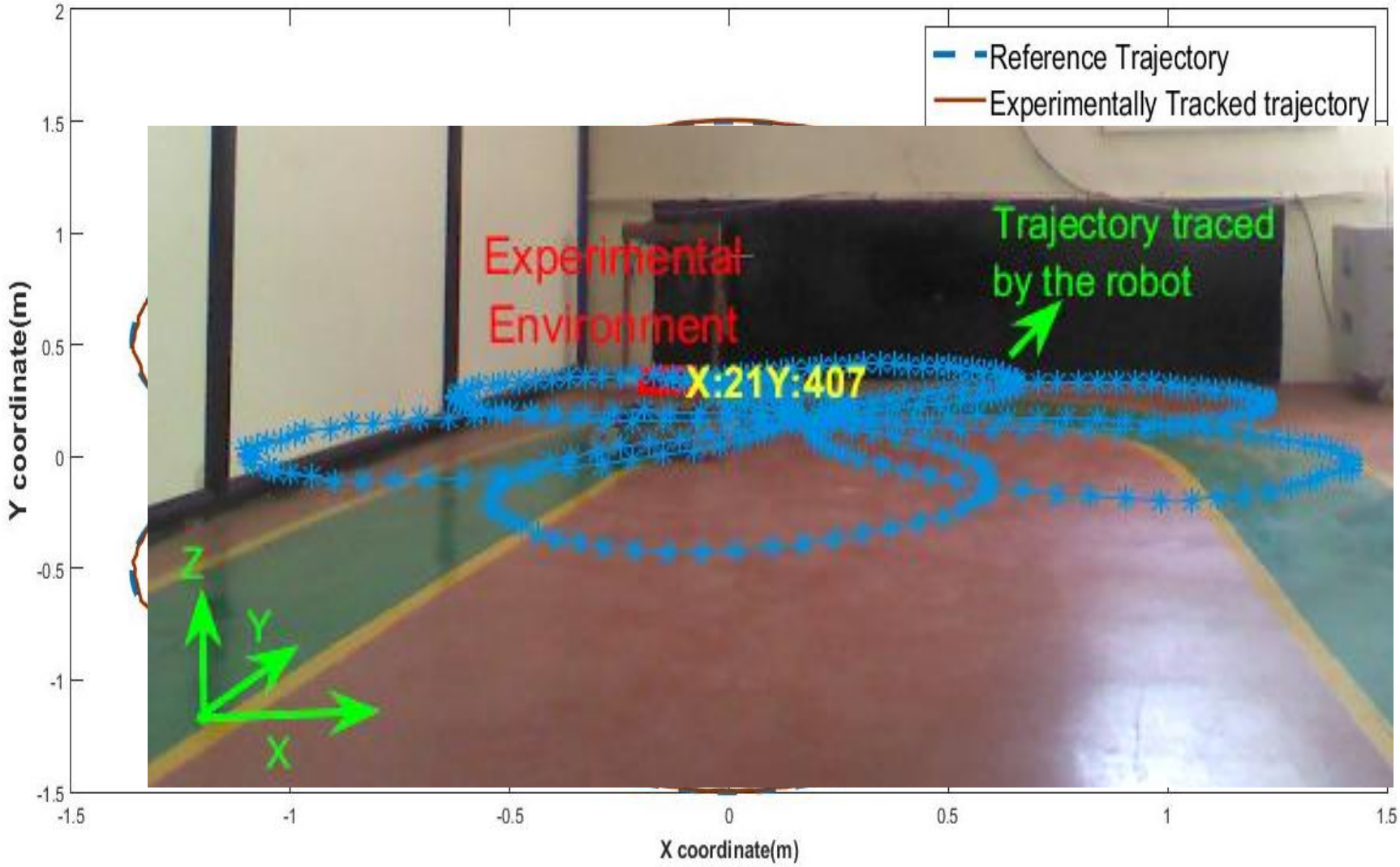
Kinect based tracking

Result Achieved



Video

Result Achieved (More complicated trajectory)



Video

Conclusion

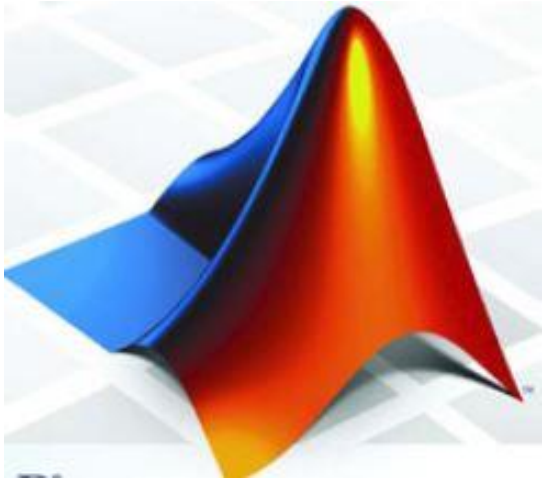
- Bond graph technique proved to efficient to model complex Multi-physical system. BGV_20 is found superior to other software like 20sim, CAMP-G etc.
- Flatness based controller essentially helps to linearize the system to get control law.
- Estimation of controller parameters using optimization tool box was efficiently done when used with simulation.
- Real time implementation of designed approach was successful due to hardware support packages.

Why MATLAB ?

Effective Tools for model based design of multi domain system

Provides all basic and advance tool for Scientific computation and research

Implementation of control strategy using different blocks in SIMULINK



Real Time Implementation

Estimation of System Parameters

Wide range of Hardware support (like arduino, Kinect and others)

Ability to conduct number of simulations and experiments


Q & A


THANK YOU