DESIGN AND CONTROL OF A MULTILINK ROBOT SYSTEM

University of Kent | School of Engineering and Digital Arts

MR BENJAMIN M. OKOCHI, DR XINGGANG YAN

Instrumentation, Control and Embedded Systems Research Group
School of Engineering and Digital Arts, University of Kent

Introduction

Robot arms find their main application in the manufacturing industry, especially automotive and electronic equipment manufacture, performing tasks such as wielding, painting, assembly and packaging. Recent technology advancements have given rise to renewed interest in Robotic research, with applications such as robotic surgery, space exploration and domestic assistive robots. The aim of this project is to design and implement a controllable multilink root system and a control strategy such that the robot will perform a given task from start to finish, for example pick an object form one location and place it at a different location.

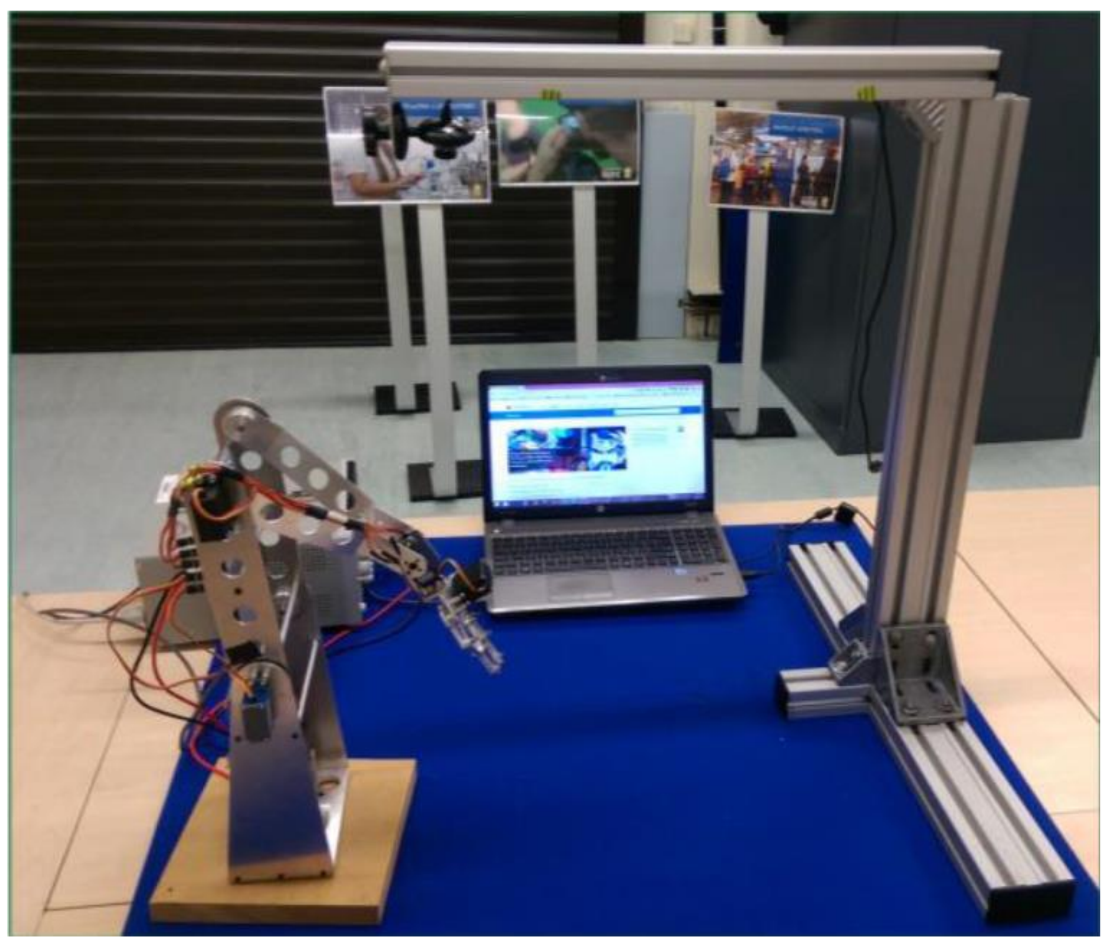

Figure 1: Robot Arm

Robot System Architecture

Figure 2 shows the robot system hardware and software architecture. Key components include motors, sensors, camera and microcontroller.

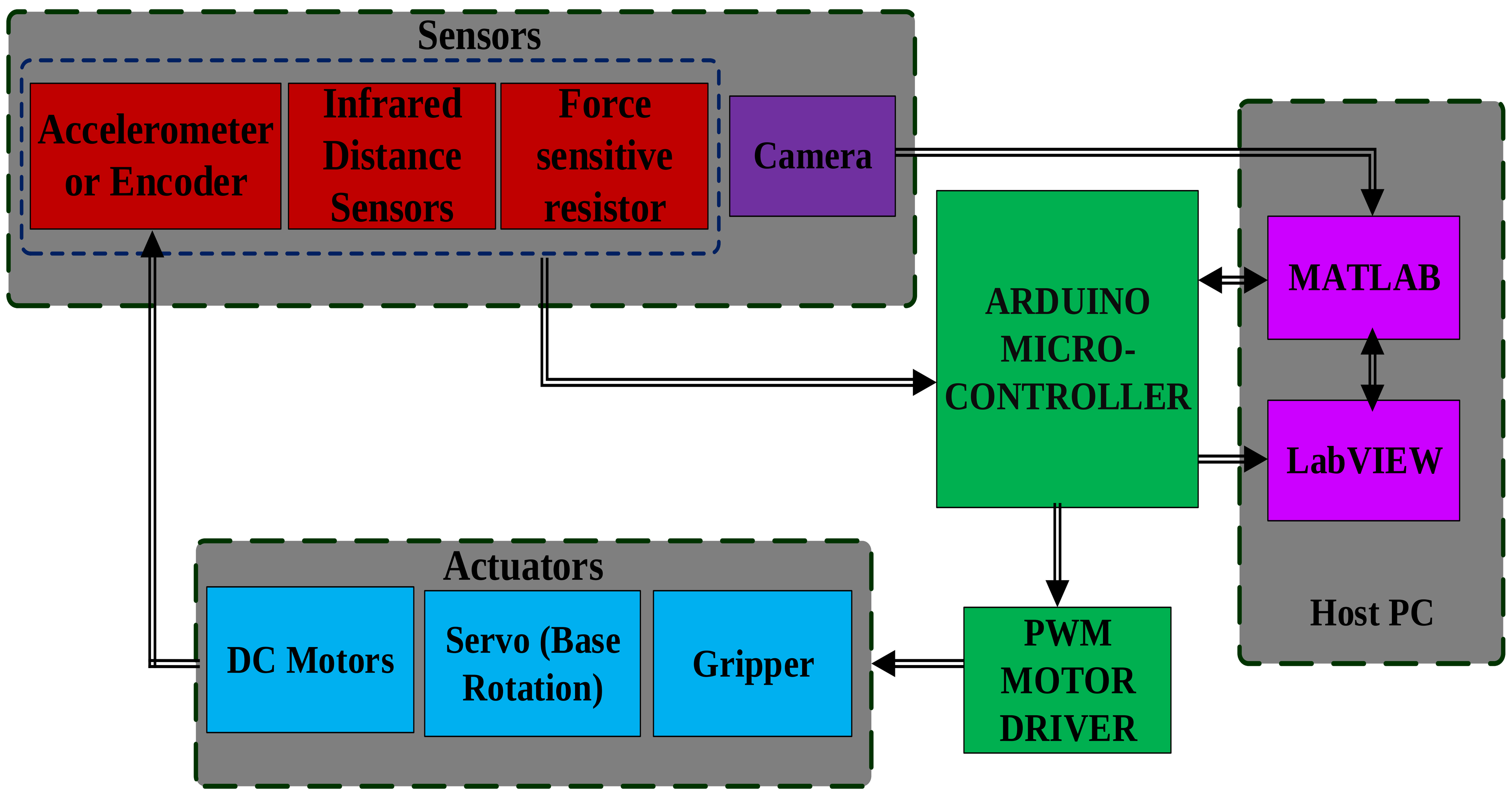

Fig.2 Robot system Architecture

Mechanical Model

A robot arm comprises of a set of rigid bodies (links), in series and connected by joints. Using a 2-DOF planar Robot arm shown in figure 3, the inverse kinematics of the arm can be mathematically solved using trigonometry:

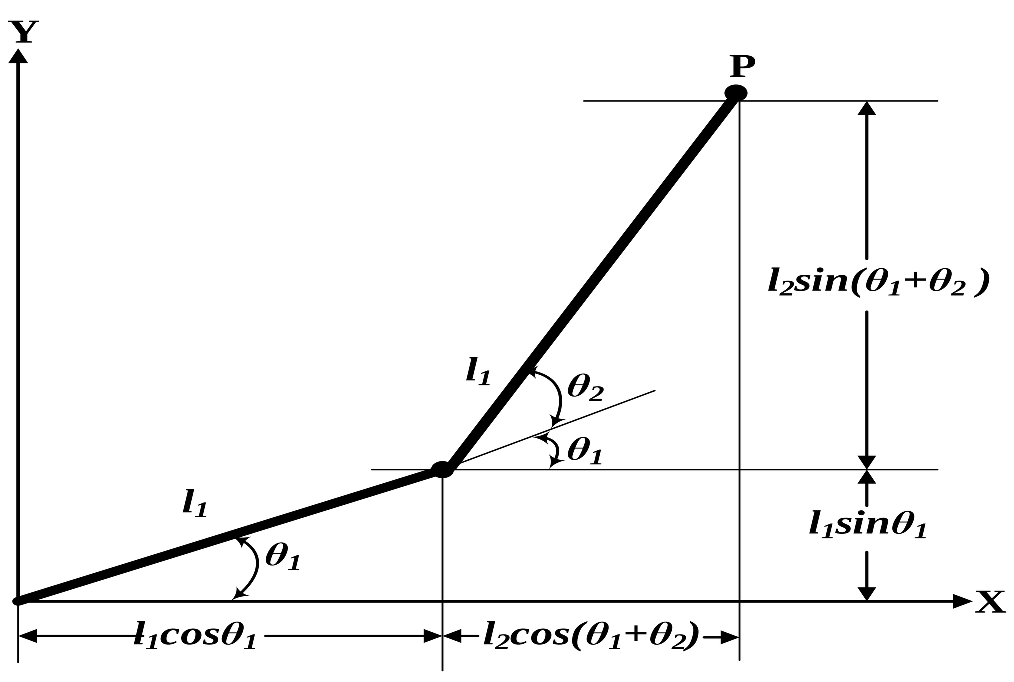

Fig. 3: 2-DOF planar Robot

$$\theta_2 = Atan2\left(\pm\sqrt{1-\left(\frac{p_x^2+p_y^2-l_1^2-l_1^2}{2l_1l_2}\right)^2},\frac{p_x^2+p_y^2-l_1^2-l_1^2}{2l_1l_2}\right)$$

$$\theta_1 = Atan2\left(\pm\sqrt{1-\left(\frac{P_x(l_1+l_2cos\theta_2)+P_yl_2sin\theta_2}{p_x^2+p_y^2}\right)^2},\frac{P_x(l_1+l_2cos\theta_2)+P_yl_2sin\theta_2}{p_x^2+p_y^2}\right)$$

The general form of robot arm dynamics is

$$\boldsymbol{\tau} = \boldsymbol{M}(\boldsymbol{q})\ddot{\boldsymbol{q}} + \boldsymbol{V}(\boldsymbol{q},\dot{\boldsymbol{q}}) + \boldsymbol{G}(\boldsymbol{q})$$

Where τ is torque, q, $\dot{q}$ and $\ddot{q}$ are position, velocity & acceleration, M is the inertia matrix, V are centrifugal and Coriolis vector terms, and G is the gravity vector term.

Control Approach

To determine the joint torques required to produce a desired trajectory for efficiently performing a task, independent joint PID Control will be used. The approach is error driven and therefore simple to implement.

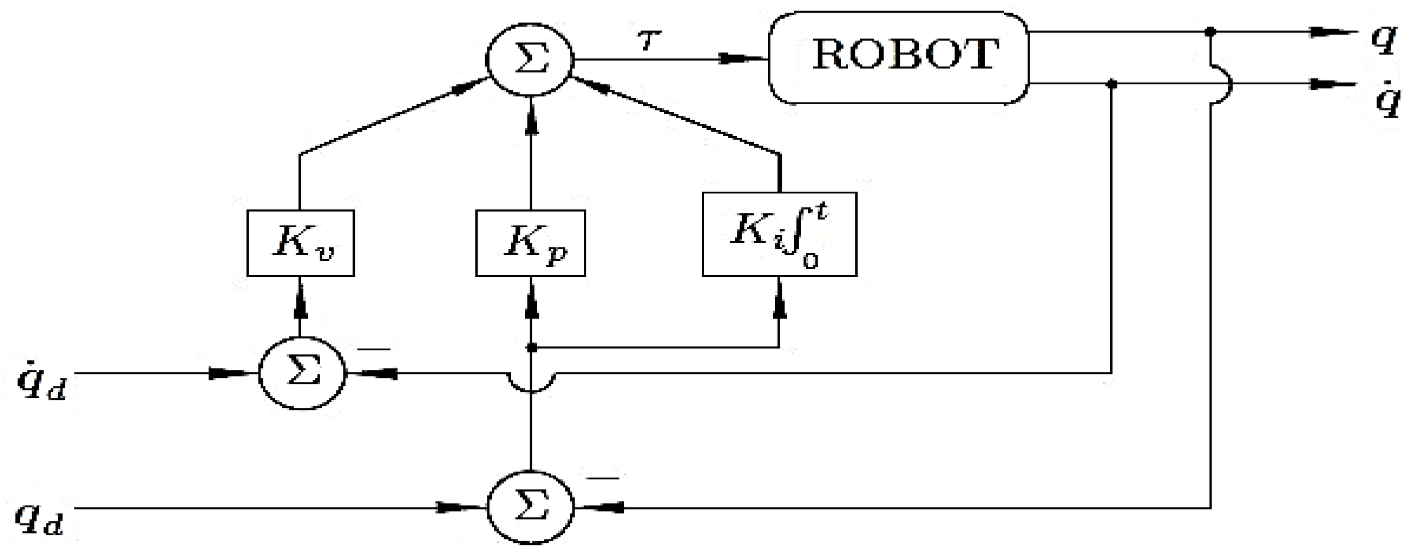

Figure 4: PID Control

The PID control law can be written as:

$$\boldsymbol{u_i(t)} = \boldsymbol{K_p(e_i(t)} + \boldsymbol{K_i}\int_0^t \boldsymbol{e_i(\tau)d\tau} + \boldsymbol{K_v}\frac{\boldsymbol{de_i(t)}}{\boldsymbol{dt}}\Big)$$

With u_i as the ith actuator torque, K_p the proportional gain, K_i the integral gain and K_v the derivative gain. $\boldsymbol{q}$ and $\dot{\boldsymbol{q}}$ are positional and velocity vector respectively.

Analysis of control approach will be done using MATLAB simulation.

Hardware

- The Microcontroller proposed is the Arduino Due based on Atmel SAN3X8E. It is open source, easy to use and well supported.
- Pololu 12V 100:1 Gear Motor with encoder
- Sharp GP2D12 range finder with range of 10-80 cm
- Logitech C525 HD Webcam with 8 megapixels for visual servoing.

Figure 5: From L to R, an Arduino board, Pololu Motor, Sharp IR range finger and Logitech webcam

Design Phases

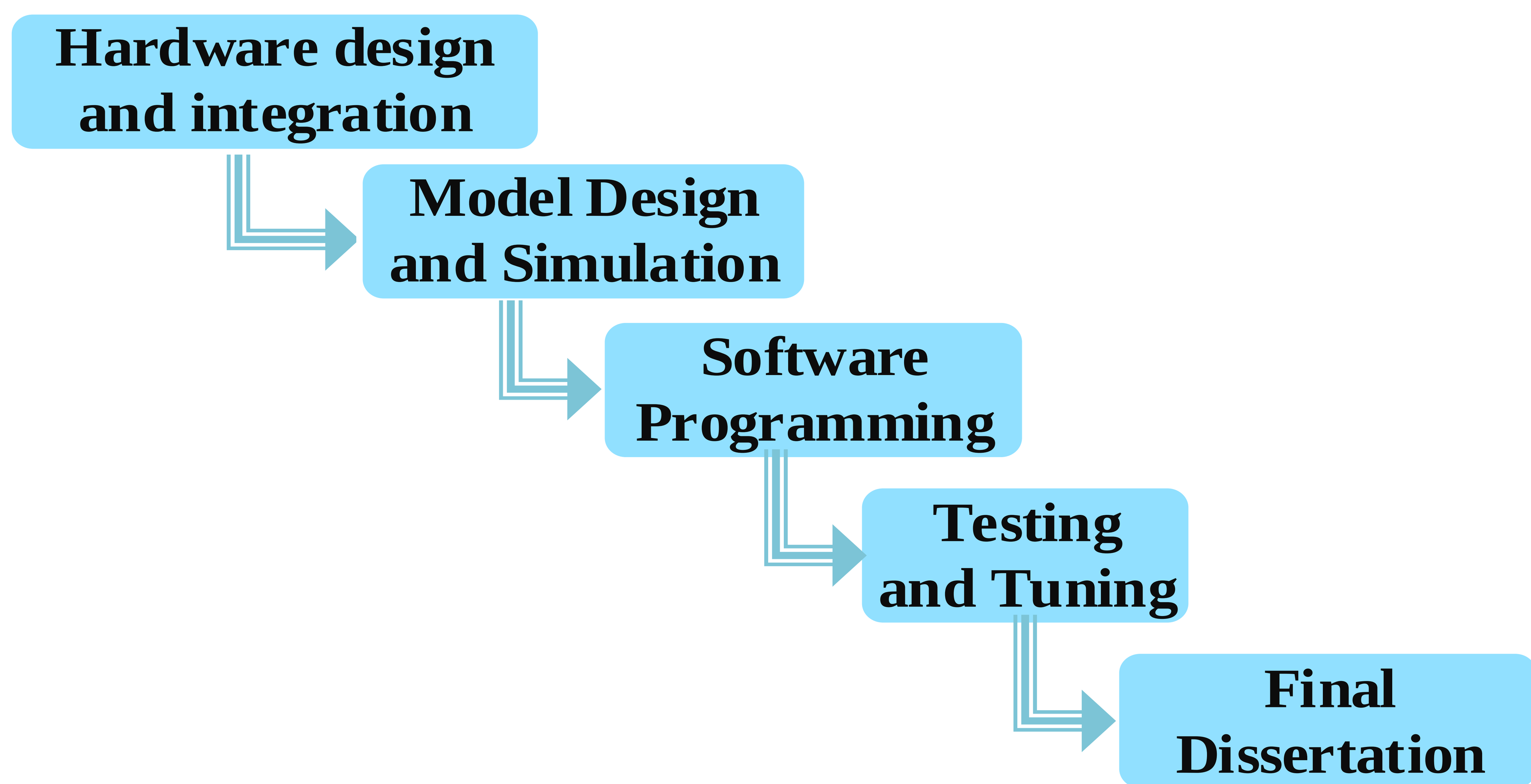

Figure 6: Phases

Conclusion

The project has multiple components that must be well integrated for it to work. Care must be taken when designing circuits to prevent overvoltage damaging components and causing delays.

Software design needs to be completed early to allow time for debugging and testing and tuning.

The project is expected to be a great learning experience and an application of various skills learnt during the year.

Contact: **Dr Xinggang Yan,** School of Engineering and Digital Arts, University of Kent, Canterbury, Kent CT2 7NT, UK
Tel: +44 (0)1227 823723 email: x.yan@kent.ac.uk Website: http://www.eda.kent.ac.uk/