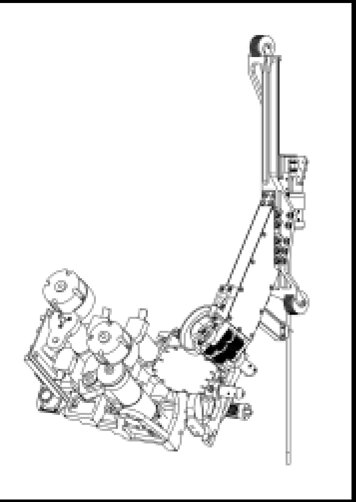
EE 449 Project Presentation V



Group 5 – Imam Tjung and Kiran Thomas

Automatic Cable Winding For Surgical Robot Arms

Milestone V

- Project Description
- Testing Rig Description
- System Modeling and Simulation
- Controller Design and Simulation
- Hardware
- Software
- Implementation
- Project Summary and Current Status
- Project Future
- References

Project Description

Customer: Bio Robotics Laboratory

Goal is to improve the cabling procedure, which currently uses a tedious method.

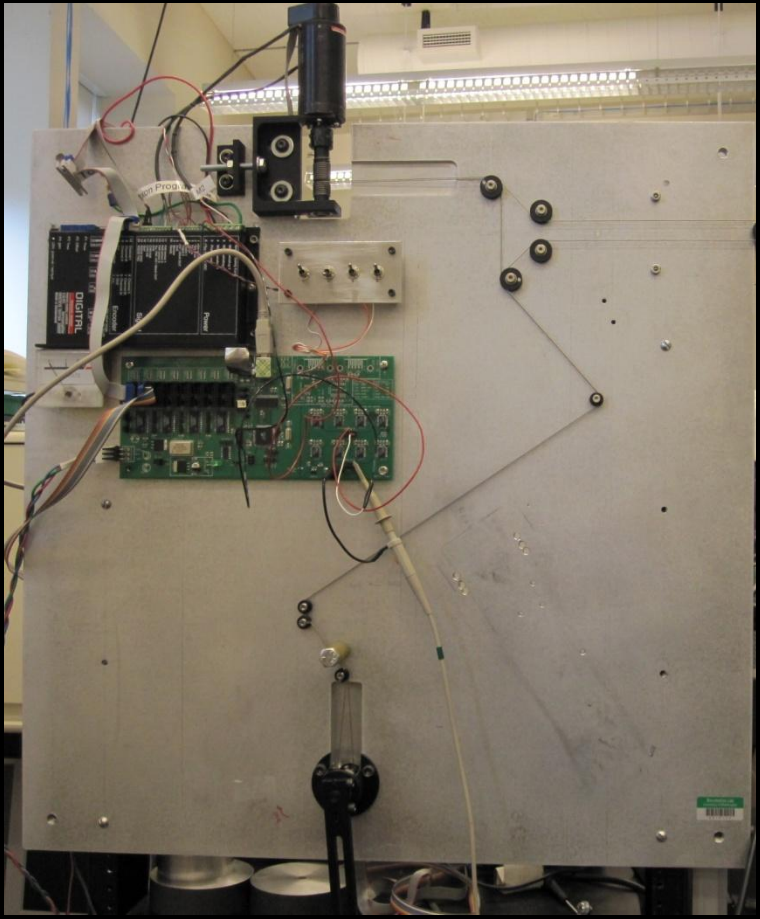
The controller we create will wind the cable onto the capstan automatically.

This will help anyone who has to re-cable the capstans since they are located at hard to reach places.

Testing Rig Description

• Pulley rig to simulate one robot motor system

•First successfully implement here before attempting on robot.



System Modeling and Simulation

- Identify plant, sensors

Electrical Equation:

Va(t) = La di(t)/dt + Rm i(t) + Kv w(t)

Mechanical Equation:

Tl(t) = Kt i(t) – bm w(t) – Jm dw(t)/dt

- State Space model

$$X = \begin{bmatrix} X1 \\ X2 \\ X3 \end{bmatrix} = \begin{bmatrix} I \\ \Theta \\ w \end{bmatrix} \begin{matrix} \text{amps} \\ \text{rad} \\ \text{rad/sec} \end{matrix} \qquad u = \begin{bmatrix} u1 \\ u2 \end{bmatrix} = \begin{bmatrix} V \\ Tl \end{bmatrix} \begin{matrix} \text{volts} \\ \text{N-m} \end{matrix}$$

$$\begin{bmatrix} dX1/dt \\ dX2/dt \\ dX3/dt \end{bmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{bmatrix} -Rm/La & 0 & -K/La & X1 \\ 0 & 0 & 1 & X2 \\ K/Jm & 0 & 0 & X3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ -bm(X3)/Jm \end{bmatrix} + \begin{bmatrix} KA/La & \Theta \\ 0 & 0 \\ 0 & -1/Jm \end{bmatrix} \begin{bmatrix} u1 \\ u2 \end{bmatrix}$$

- Model Parameters

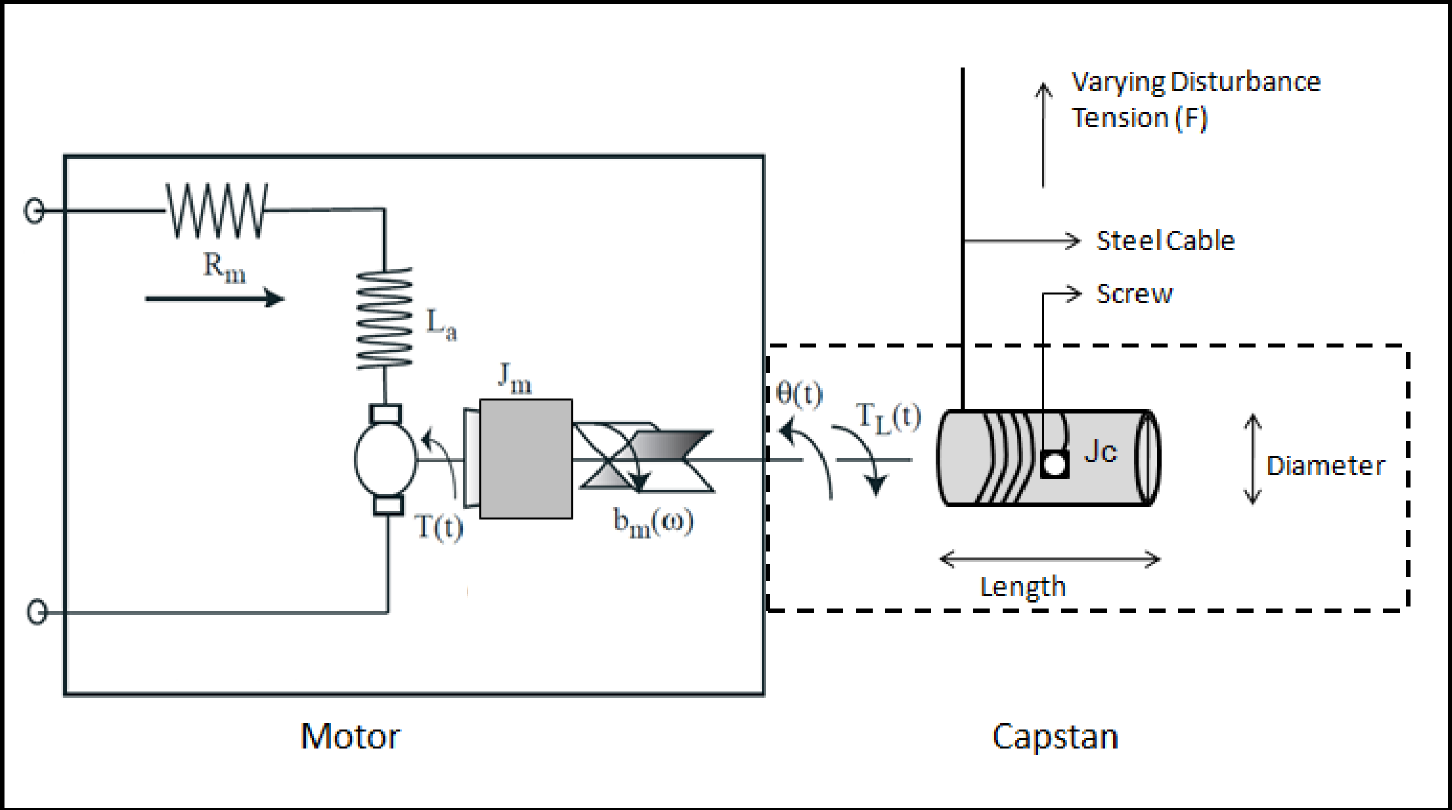
Electrical Parameters:

- Self inductance (La) = 1280 mH
- Terminal Resistance (Rm) = 4.94 ohms

Mechanical Parameters:

- Torque to Speed Ratio (Bm) = 1.1507e-3 Nm/(rad/sec)
- Plant inertia (Jm) = 85 gcm^2 + 21.932 gcm^2
- Torque constant (Kt) = 0.09167 Nm/Amp

System Modeling and Simulation

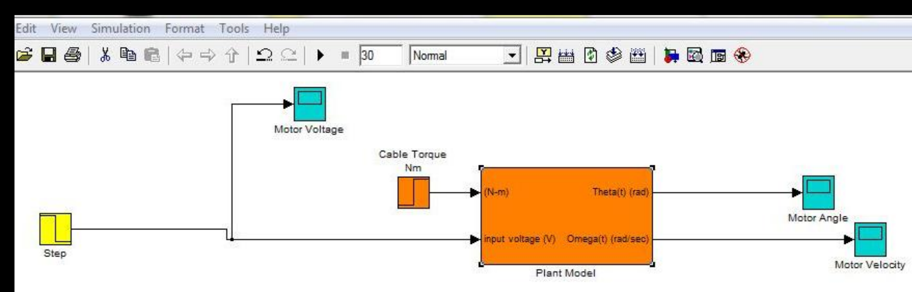


System Modeling and Simulation

- Controllability
- Observability
- Open loop simulation in MatLab

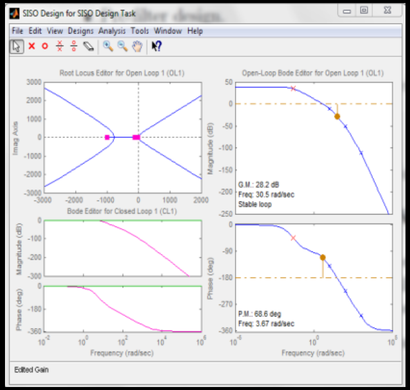
```
>> Cm = ctrb(A,B)

Cm =

  1.0e+009 *

    0.0000         0   -0.0000   -0.0000    0.0000    0.0007
         0         0         0   -0.0001    0.0000    0.0101
         0   -0.0001    0.0000    0.0101   -0.0007   -1.1382

>> rank(Cm)

ans =

     3
```

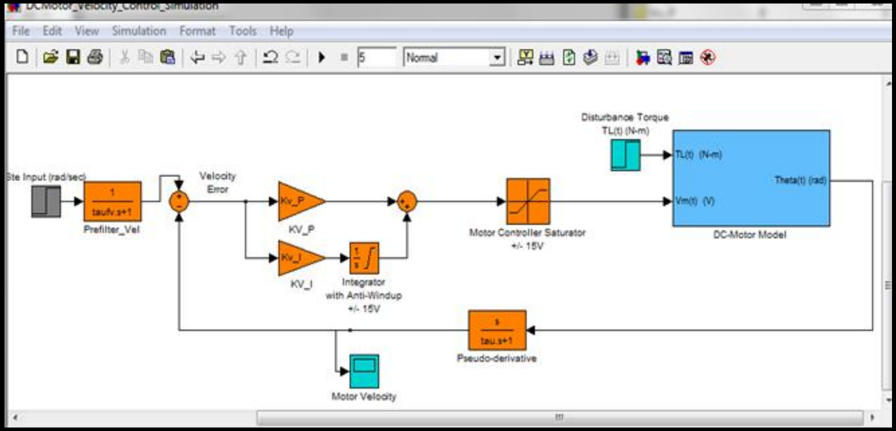
```
>> Om=obsv(A,C)

Om =

  1.0e+003 *

         0    0.0010         0
         0         0    0.0010
    8.5672         0   -0.1075

>> rank(Om)

ans =

     3
```



Controller Design and Simulation

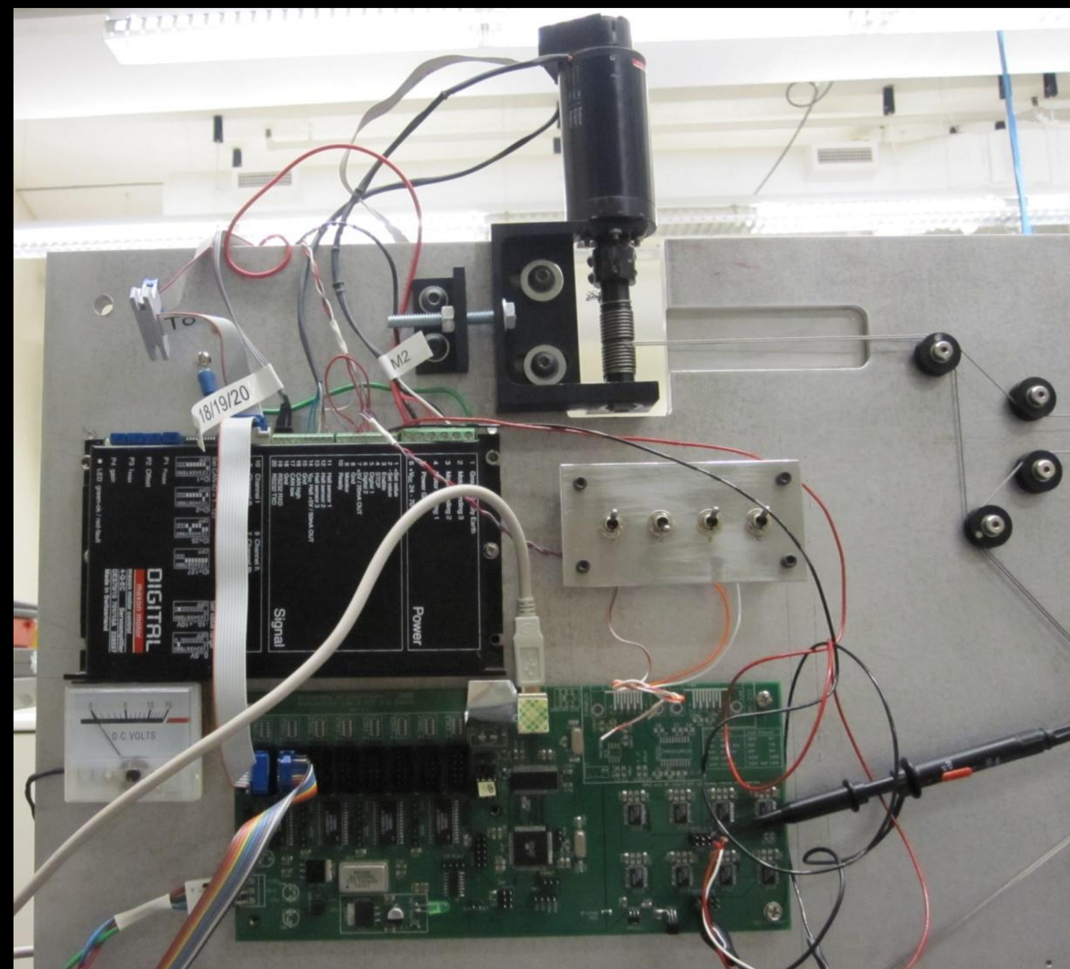
- Controller choices
- Controller Design
- Closed loop simulation in MatLab
- Performance and Stability evaluated





Hardware

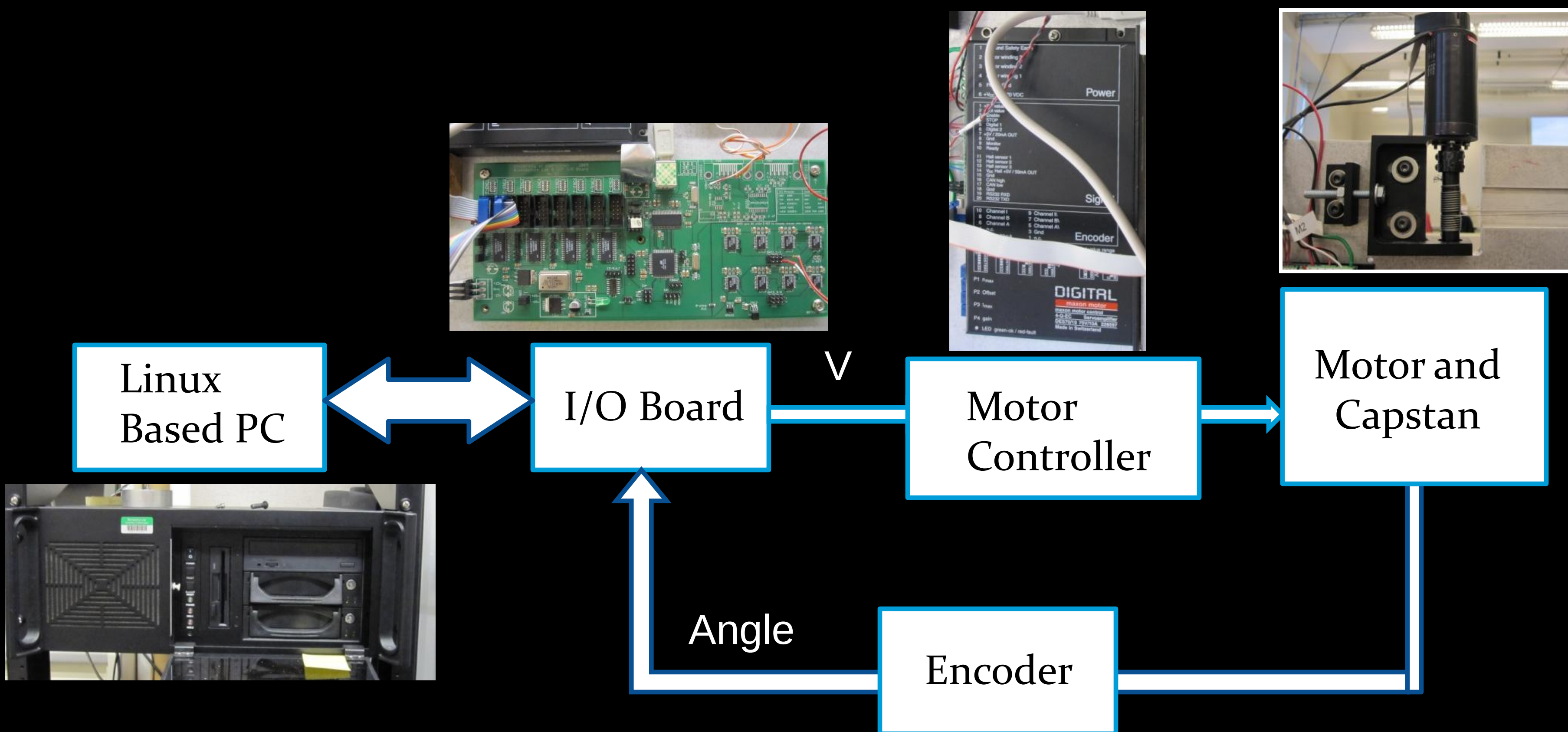
- Motor
- Encoder
- Capstan and cable
- Motor Controller
- I/O Board



Software

- Fedora 3 Linux PC
- Coded using C.
- State machine
- Programmable foot pedal

Signal Flow



Linux Based PC
I/O Board
V
Motor Controller
Motor and Capstan
Angle
Encoder

Implementation

- C code rotates in both directions.
- Run separate programs for each direction. The system uses one cable.
- Range of motor torque limited to level manageable by a person

Video

Current Status and Future

- Completed rotating in both directions
- Challenge switching between states while program is running (Foot Pedal)
- Position Control

Future:

Main user is the student in USC and it will help with contruction and assembly

Project Summary

During the course of the quarter we learned:

- Application of control principles
- Real world challenges, planning for obstacles
- Regular re-design and goal updates depending on customer requests
- Project planning, technical presentation and reports

References

E Naerum, H. Hawkeye King, B. Hannaford**, 'Robustness of the Unscented Kalman Filter for State and Parameter Estimation in an Elastic Transmission**,' Proceedings Robotics Science and Systems 2009 (http://www.roboticsproceedings.org), Seattle, July 2009.

Atef Saleh Othman Al Mashakbeh**, "Proportional Integral and Derivative Control of Brushless DC Motor"** European Journal of Scientific Research
ISSN 1450-216X Vol.35 No.2 (2009), pp.198-203
-Used the author's method to model the BLDC motor.

Norman S. Nise, "Control Systems Engineering", Wiley 2008
-The techniques for assessing controlability and observability were obtained from this book

Uy-Loi Ly, "DC Motor Control", 2010, https://courses.washington.edu/aa448/DCMotorControl_LabDescription.pdf
-Used to determine the simulink simulation.

"Maxon EC Motor Data Sheet", 2010. http://shop.maxonmotor.com/ishop/article/article/118898.xml
- Used to get the model parameters