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# Torque Control for a Joint Actuated by a Brushless Motor

## Proposal for Master Thesis

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# Torque Control Strategies for a Joint Actuated by a Brushless Motor

## Motivation:

This Master Thesis aims at evaluating two alternative control strategies for a robot joint composed of a brushless motor and harmonic drive. First part of the thesis will implement a torque control based on a vector control technique for the brushless DC motor in simulation. Then, in the second part, a Torque-to-Position transformer will be added to the existing joint position control of AILA. The final results will be implemented and tested on the real joint.

## State of Art:

Permanent Magnet Synchronous motors which have a trapezoidal-induced emf are known as the Brushless DC motors (BLDC). Brushless DC motors offer several advantages over traditional brushed AC and DC motors, including lower materials costs, greater reliability, reduced noise and longer lifetime. However, since brushless motors can not self commutate, torque control, which is fundamental to successful operation of any servo system, presents a more complex challenge. Therefore, a wide range of control algorithms are applied and three main types of motor control are shown and compared in the Table 1:

| Control Types | U/f Control | Vector Control | Direct Torque Control |
|---|---|---|---|
| Advantages | Low price | Accurate speed control<br>Good torque response<br>Full torque at zero speed | Torque response is fast |
| Disadvantages | Torque is not controlled | High cost | Performance at lower speeds is not satisfactory |

**Table 1: Three Main Types of Motor Control**

In order to control a BLDC, the control strategy chosen should be capable of good and fast torque response. Vector control, through mathematical coordinate transformation, decouples three-phase stator currents into two-phase dq-axis rotor currents, one that produces flux and the other that produces torque.

Compared to the other control methods, the Vector Control offers multiple benefits including accurate speed control, good torque response and wide speed range by directly weakening the flux. Figure 1 illustrates the vector control for a BLDC:

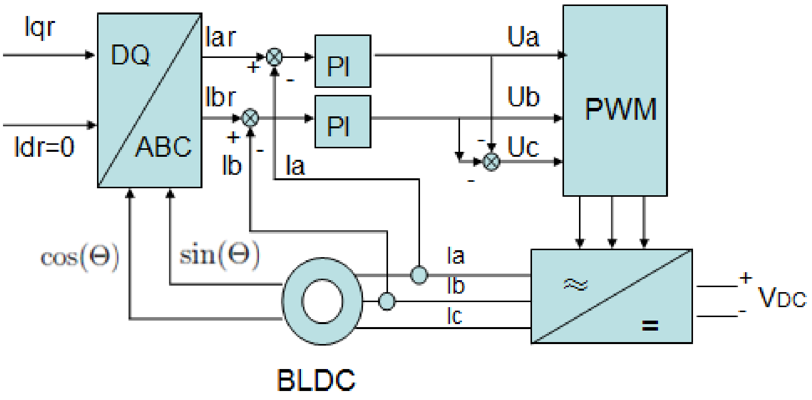


**Figure 1: Vector Control for a BLDC**

In this project, a torque control based on a vector control technique will be implemented for the brushless DC motor. Due to the lack of a torque sensor, an observer can be used instead to estimate the torque feedback. Figure 2 shows the torque control for the BLDC:

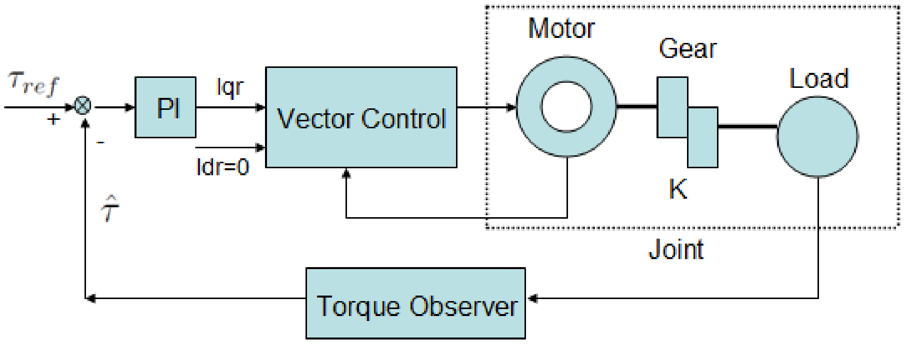


**Figure 2: Torque Control Based on a Vector Control Technique**

Position control is used widely in industrial robotics. However, since it cannot account for the dynamics of the system, the performance of conventional joint position control limits high performances in advanced robotic tasks. In order to address this problem, a Torque-to-Position transformer can be used to allow torque control based algorithms to be applied to position-controlled robots. As illustrated in Figure 3, the input torque $\tau_{des}$ for the system can be designed to accomplish the desired tasks and compensate for the dynamics of the system. The corresponding position $\Theta_{desired}$ is determined according to the transformer and it will be used as the input for the position controller which is currently used in AILA. The control strategy with Torque-to-Position transformer is depicted in the Figure 3:

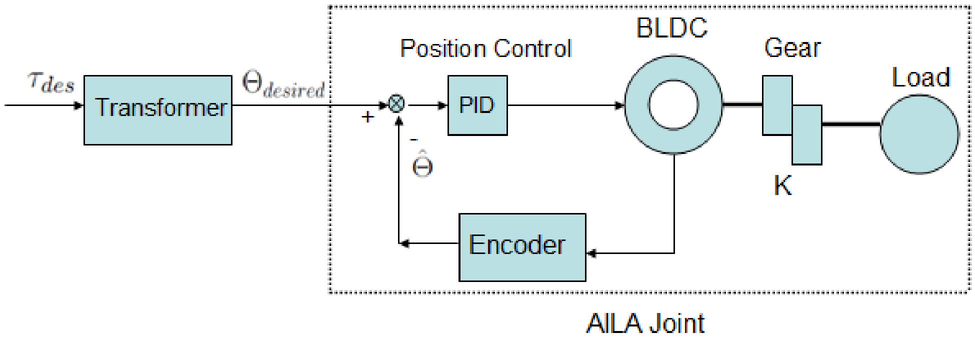
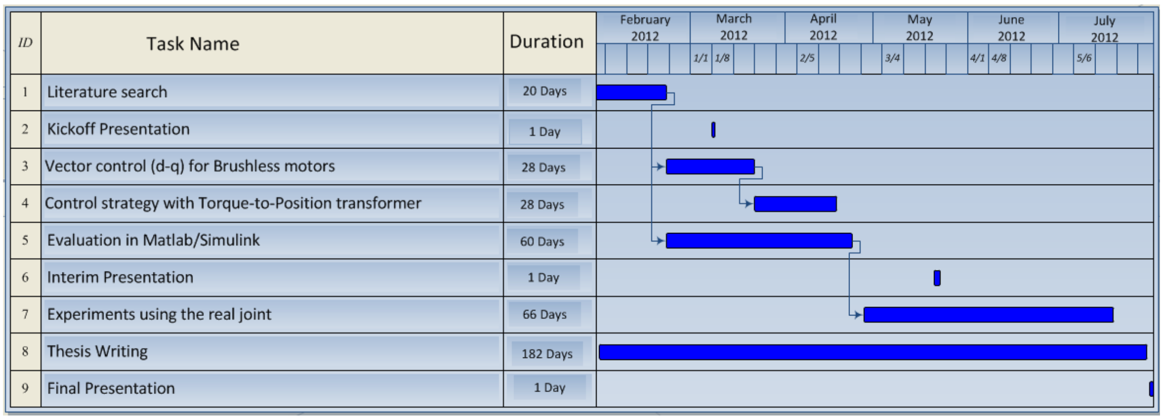


**Figure 3: Torque Control with Torque-to-Position Transformer**

## Workplan:

- State of the art on brushless torque control and flexible joint control
- Vector control (d-q) for Brushless motors
- Control strategy with a Torque-to-Position transformer
- Evaluation in Matlab/Simulink
- Experiments using the real joint (Real-Time Matlab or DSpace)

The time schedule of the thesis is shown in Table 2:



| ID | Task Name | Duration |
|---|---|---|
| 1 | Literature search | 20 Days |
| 2 | Kickoff Presentation | 1 Day |
| 3 | Vector control (d-q) for Brushless motors | 28 Days |
| 4 | Control strategy with Torque-to-Position transformer | 28 Days |
| 5 | Evaluation in Matlab/Simulink | 60 Days |
| 6 | Interim Presentation | 1 Day |
| 7 | Experiments using the real joint | 66 Days |
| 8 | Thesis Writing | 182 Days |
| 9 | Final Presentation | 1 Day |

**Table 2: Time Schedule**

## Literature:

[1] R.Kirshnan: *Permanent Magnet Synchronous and Brushless DC Motor Drives*

[2] Erwan Simon: *Implementation of a Speed Field Oriented Control of 3-phase PMSM Motor using TMS320F240*

[3] Guoguang Zhang, Member, IEEE, and Junji Furusho: *Speed Control of Two-Inertia System by PI/PID Control*, IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 47, NO. 3, JUNE 2000

[4] Junji Oaki and Shuichi Adachi: *Decoupling Identification for Serial Two-Link Robot Arm with Elastic Joints*

[5] Yoichi Hori: *Vibration Suppression and Disturbance Rejection Control on Torsional System*