

Feedforward Controller of Precise Positioning System by MPT



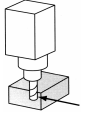
FL08-18-2
Hiroshi Morioka



Introduction

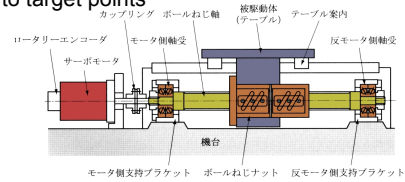
Positioning system

- Control that moves object to a target point and stops
- Evaluated by positioning time and positioning accuracy



Positioning mechanism treated by this research

- Mechanism that rotates ball screw by motor, and moves table to target points

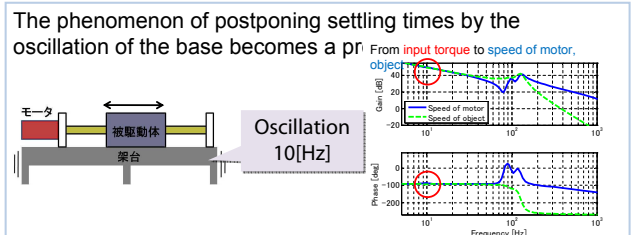


Outline

- Problem
- Design FF Controller
- Model Change
- Conclusion



Problem1



Earlier methods

- Remove the oscillation frequency from the instruction
- Linear feedback(observer + state feedback etc...)

Bad Robustness

- Model uncertainty
- Deterioration of observability

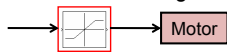


Limit of linear controller



Problem2

the saturation of the motor voltage becomes a problem



Voltage Saturation

- The differential motor torque is a great factor
- Index of the impact given to the machine

- Consider the constraint of the differential torque
- The simplicity of FF seems to be higher than that of FB



Design FF controller by Hybrid Predictive Control

FF : Feedforward
FB : Feedback

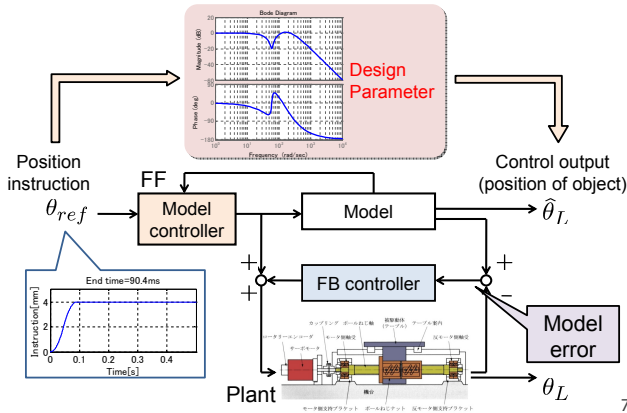


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Controller Structure (2 degree of freedom)

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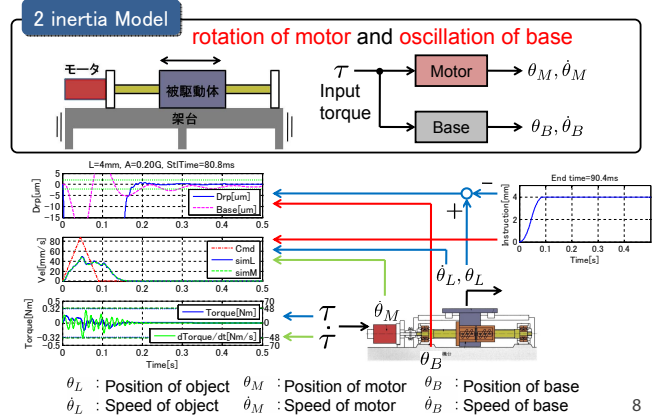
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Model

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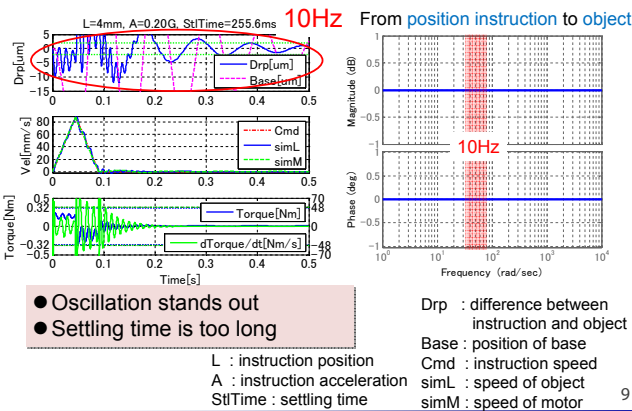
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Simplest FF Controller

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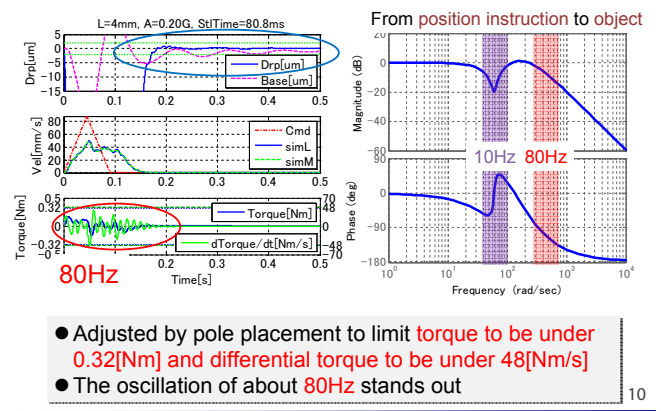
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Earlier FF Controller (Pole Placement)

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Design of FF Controller

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Limit of Earlier FF Controller

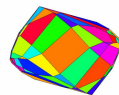
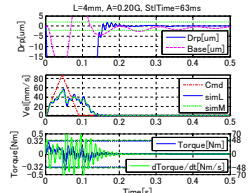
- The input breaks the constraint when response is fast
- The response oscillate

Design with MPT

- Design that considers constraint by using MPC
- Improvement of performance by a high degree of freedom

MPT is based on LQ and PWA state feedback

It is necessary to make response preferable with LQ



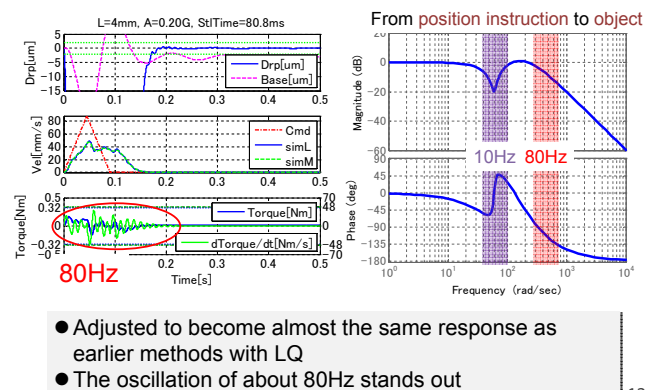
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LQ FF Controller

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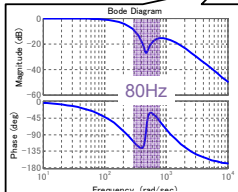
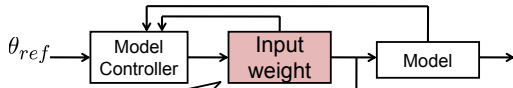
Control of oscillation (80Hz)

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- The input breaks constraint by the oscillation of 80Hz

Before MPT is applied, we suppress the oscillation of 80Hz

Frequency shaping



Frequency shaped LQ is based on LQ, so easy to apply to MPT

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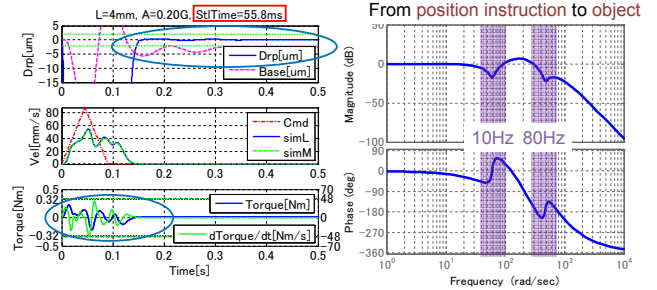
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Frequency Shaped FF Controller

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- Suppressed the oscillation of 80Hz by frequency shaping
- Settling time is shorter than previous one

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MPT FF Controller

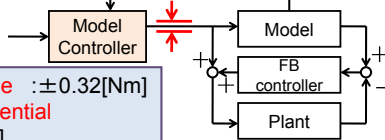
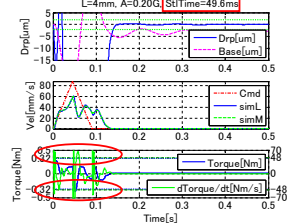
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Limit of Linear Controller

- The input breaks the constraint when response become fast
- It is difficult to control a great performance gain in a linear control

Hybrid Predictive Control

- Design that considers constraint by using MPC



Constraint of torque : ± 0.32 [Nm]
 Constraint of differential torque : ± 48 [Nm/s]

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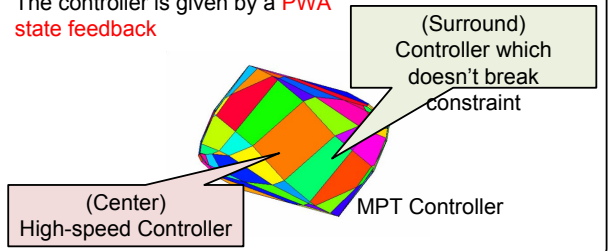


MPT FF Controller (Image)

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Image of MPT Controller

The controller is given by a PWA state feedback



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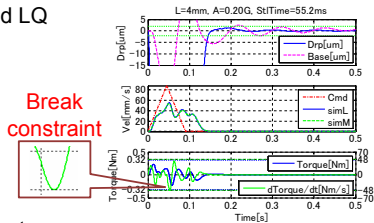
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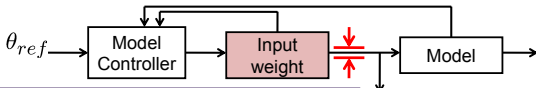
Example of MPT

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- Design the controller which breaks the constraint with frequency shaped LQ



- Constrain the input



Constraint of torque : ± 0.32 [Nm]
 Constraint of torque differential : ± 48 [Nm/s]

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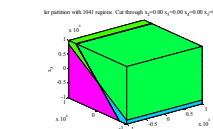
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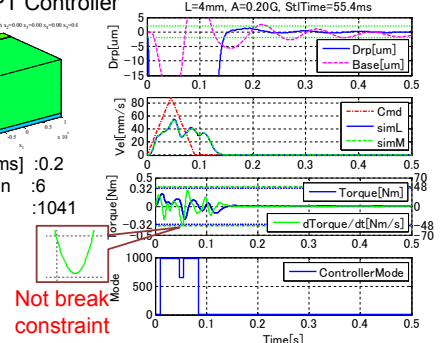
Example of MPT

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- Calculate MPT Controller



Sampling time [ms] : 0.2
 Receding horizon : 6
 Region : 1041



Not break constraint

The controller switches not to break the constraint

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Problem

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Problem

- No solution when severe constraint is given
- Because prediction time is short, appropriate solution is not outputted
- There is no guarantee that the input of the plant doesn't break the constraint



When the target value is changed, it sometimes diverge

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Improvement Plan

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Improvement Plan

- Change the model
- Change the FB controller
- ...

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Outline

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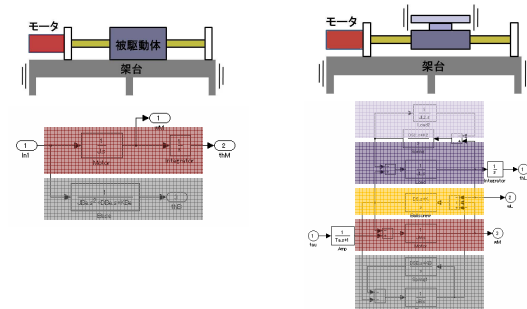
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Model Change

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- Change from 2 inertia model to 4 inertia model



It is possible to control accurately by using 4 inertia model

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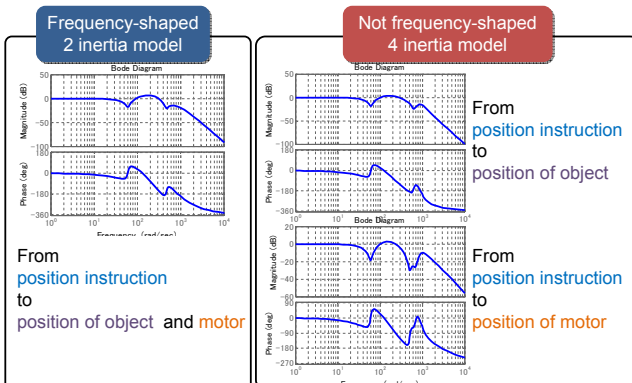
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Difference of Frequency Response

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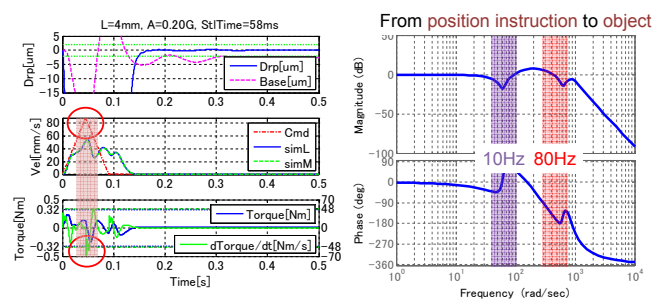
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LQ FF (4 inertia model)

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- Designed with LQ
- The differential torque change greatly at the switch of the target acceleration

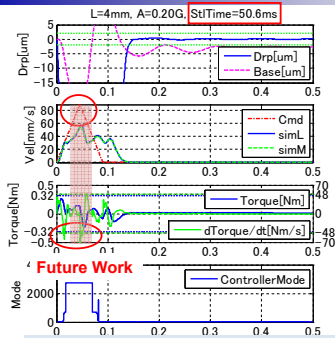
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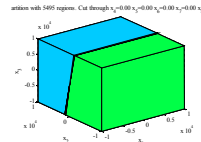
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MPT FF (4 inertia model, with constraint)

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Torque constraint
:±0.32[Nm]



Sampling time [ms] :0.2
Receding horizon :9
Region :5495

- The constraint is put on torque
- The differential torque greatly at the switch of the target speed

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Outline

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- Problem
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Conclusions and Future Works

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Conclusions

- Treated FF controller of positioning system
- Suppressed the oscillation
- Use the input constraints
- Model change

Future works

- Robust stability, Robust performance
- FB controller

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Reference

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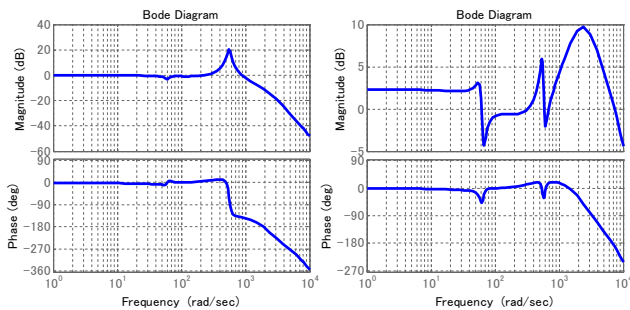
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[Appendix1] Bode of simplest FF

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From **instruction**
To **position of object of plant**

From **instruction**
To **position of motor of plant**

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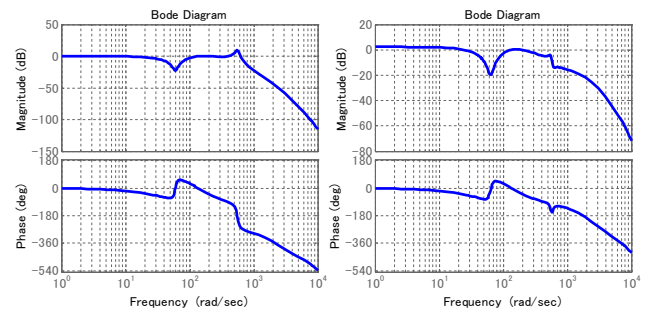
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[Appendix2] Bode of pole placement

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From **instruction**
To **position of object of plant**

From **instruction**
To **position of motor of plant**

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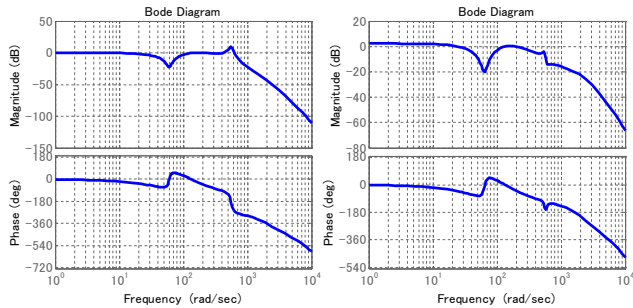
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[Appendix3] Bode of LQ

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From instruction
To position of object of plant

From instruction
To position of motor of plant

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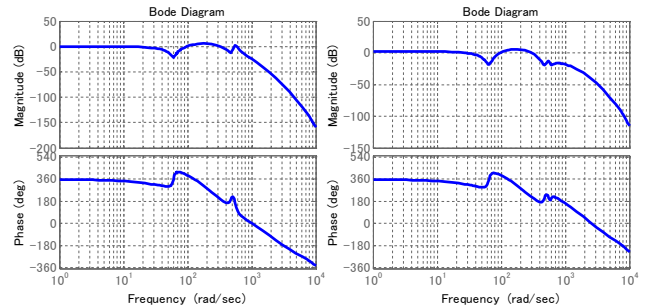
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[Appendix4] Bode of frequency shaped LQ

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From instruction
To position of object of plant

From instruction
To position of motor of plant

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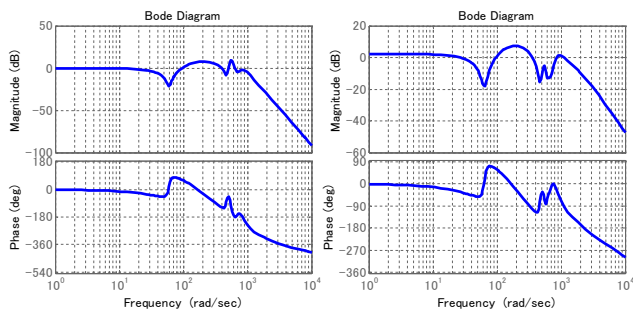
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[Appendix5] Bode of LQ (4 inertia)

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From instruction
To position of object of plant

From instruction
To position of motor of plant

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