**CHAPTER 4: OPTIMAL CONTROL**

* Lagrangian
* Lamba: nhân tử lagrange (Vector)

Change into cost/performance function -> energy of the system -> use for input controlling use -> control any system -> minimize value of the energy using -> and want it stable -> OBJECTIVE…

Derive the performance function of optimal control in Equation 4.1.6

Obtain in Equation 4.1.7 (Euler – Lagrange)

Assumption, have delta lambda is free => = 0;

Hightlight the equation 4.1.19

4.1.1 => How to Minimum the control effort (which mean the energy)

Chủ yếu phần này người ta đang có ví dụ đơn giản với 1 hàm đơn giản nên – có thể hình dung ra để áp dụng cho các hệ thống phức tạp hơn.

**4.2 Pontryagin’s Maximum Principle** => Different with the performance function

* REMEMBER the principle

4.2.1 and 4.2.2 the same with performance function

4.2.4: the assumption

4.2.5: following the develop function

4.2.6: the main principle

* Follow the Halminton
* 4.2.9
* 4.2.20: Find the initial of input control following the Halminton Rule

**4.2.2: Performance Functionals with Terminal Cost**

Different from the former function

2 terms:

h : we must evaluate base on potential and kinetic energy of the final time -> find it ourselves -> cannot fit -> cuz it belongs with our system

* Replace the constant into this system

Special case: modification: constant \* with variation of the system here = h

1 term: terminal term-> not use it as a zero value -> cannot apply the optimal control in a real system.

2nd term: the progress of calculation -> stable to hold something

Terminal cost function -> Terminal value in our final time in the system

Share: some mathlab code about the optimal control – can follow and modify for us system

**CHAPTER 5: THE LINEAR QUADRATIC REGULATOR (LQR) PROBLEM**

* This also belongs to the optimal control

*5.1 The Kalman Problem*

The origin of Kalman => relate to optimal control => follow the optimal control

5.1.1

5.1.2:

X(tf): define the final time of the system stable – we must know about the final time – the feature of optimal control

5.1.3: Cost function

2 terms:

1 term: terminal term -> terminal cost function (H)

2 term: progress term (Q, R)

Why we have ½ in this: kinetic and potential energy -> potential can neglect but the kinetic can not neglect -> in calculate the kinetic -> always have the constant ½ exist at the first of the function -> default -> the reason exist ½ in the function

* Following the kinetic energy
* Can replace by 100 – it is okay – but when run the cost it will have the problem -> may be the system not stable after the final time

The prob how we can find the matrices here -> cannot find by the solving: -> study later -> but here remembers the form.

* Use Halminton Equation again (5.1.4)
* Replace the above and have the equation 5.1.5
* Now we do not say “Optimal control” but it will LQR control
* Then just follow step by step in the next page

5.1.12: teminal => final time of stable

5.1.16: Kalman of the progress => to 5.1.19 is processing

- take the derivative => change the name from Kalman to Riccati

In the equation 5.1.21: this can find the initial of value of Q

Then use this Q for the equation 5.1.23

* Then we can find all the matrix => all just find the input control.

**Follow the principle in Figure 5.2:**

Find the example of LQR from the equation 5.4.11 continue to the end.

* This is also the method of the optimal control calculation.

5.5 THE TRACKING PROBLEM WITH DISTURBANCE -> can defer as a noise (disturbance)

5.5.2: Decide the initial condition

5.5.3: Decide the problem follow the trajectory

=> M is a matrix is design by trajectory

5.5.4: Like the Kalman

5.5.5: Processing

5.5.6: Performance function

3terms:

* 1st term: Terminal term
* 2nd term: progressing term
* 3rd term: the error of our system

Define forlow the t\_non ? use the matrix H, Q, R

After this

* Define the Halminton

5.5.8: like the input control

5.5.13: progress – shi(t)

Why decide this term shi(t) -> always exist a disturbance -> so the term shi(t) here is replace for the disturbance – use (-) cuz move on to remove or reduce the disturbance

So how can calculate -> follow step by step to 5.5.16

Use the 5.5.17 and follow up to calculate 5.5.16

The input control must follow 5.5.18 – the form

**CHAPTER 9:**

9.1 Initial control input function

9.2: assump the system is stable

9.3: đọc slide -> nó là cost function

Just follow the optimal control 9.2.20 -> continuos

9.2.24: for the continuos system not different – still follow the Halminton

9.6 for practice at home -> optimal control for discrete system -> try to replace other values of our system

**CHAPTER 12: THE LINEAR QUADRATIC GAUSSIAN PROBLEM (LQR)**

Why use the gaussian here ?

Gaussian related the probability -> don’t know the time of distrurbance happen -> use this to evaluate the that time with probability appears.

In the optimal model: x=Ax + Bu +w

W is Gaussian white mean zero -> google calculate the covariance Q

12.1.4: why use the epsilon – it follows the Bayes’s theorem -> foillow the probality

Subititue the epsilon into cost function

Obtain the 12.1.8 -> 12.1.9

2012 Bssin:

Equation (2): is related to the Equation (3)

**3. Optimal control problem solution**

The optimal control law takes the sliding mode control form

 (Equation 4)

Equation 5 follow the adaptive law

2 of these is the new equation in the optimal control problem solution

In boundaries case;

We need min – max value for the input control.

Sacobian ? apply ?

RESEARCH: HARDWARE…. [1.pdf] - ROBOTIC

Algorithm: hardware in the loop – related – Kalman – Input Control

* the equation (1) and (2), (3)
* define the variation
* Equation 1st in the A. Constrained Linear Quadratic
* Next is Equation (5) and (6)
* Hamilton is Equation (8)
* Linear Transformation Equation (11), Equation (12), Equation (13)
* Equation 12, 13 can solve by 4th order Runge-Kutta method – [in Matlab command is ode45]
* Final is Equation 14,15

THE REVIEW: 2024 CHAP1 P1 LQR:

* Finite time LQR
* Infinite time LQR
* Applying LQR Control
  + Trajectory generation:
    - Can apply for any system – follow the slide
  + Trajectory tracking
    - LQR for trajectory tracking
      * Define the error:
        + Approach: regulate the error trajectory
        + Choosing LQR weight:

Can choose matrix Q and R: recommend in the slide – this can find and generate as parameter

* Application: Cruise control
  + Q is different 0 - > appear phenomenal -> time delay -> this happen in the system response is delay
* LQG (Linear Quadratic Gaussian)
  + Optimal state estimation (LQE) -> estimation here also relate to the Gaussian to calculate the covariance

**ADVANCED SLIDING MODE CONTROL FOR MECHANICAL SYSTEMS**

**(sách của tác giả Trung thì dễ hiểu hơn – xong roài mới qa sách ngừi Tây)**

**[2024 chap 2 SMC]**

Definition 2.3: can apply for optimal control

Slide mode control:

Equation 2.18: (from 2.13 – 2.17 to come up the 2.18)

* The state stability is not converted to 0 (always appear as the boundaries) -> this apply transform from nonlinear to linear (Figure 2.1)

3.5.2 Single input control structures

Application 2:

Conclusion cases for the system:

* Stable <node>:
* Unstable <saddle>:
* Marginally stable <center>:
* Stable <spiral sink>
* Unstable <spiral source>

Switching rule and plan mode control

Sliding Mode control: For the update of