MINISTERUL EDUCAȚIEI
UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA

FACULTATEA DE AUTOMATICĂ ȘI CALCULATOARE
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Nr. înreg. **37790/23.10.2024**

Către,

Conducerea Universităţii Tehnice Cluj- Napoca

Subsemnata Bîrs Isabela Roxana, având funcția de Șef Lucrări/Lector în cadrul Departamentului de Automatică, Facultatea de Automatică și Calculatoare, înaintez prin prezenta documentele necesare pentru obținerea gradației de merit pe baza activității profesionale deosebite, desfășurată în perioada 2021-2023.

Data,

22.10.2024

Semnătură,

UNIVERSITATEA TEHNICĂ DIN CLUJ-NAPOCA

FACULTATEA DE AUTOMATICĂ ŞI CALCULATOARE

INFORMAŢII PERSONALE

Numele şi prenumele	Isabela Roxana Bîrs
Telefon / Fax	**0264 401 820**
E-mail	**Isabela.Birs@aut.utcluj.ro**

EXPERIENŢĂ PROFESIONALĂ

• Data	2015 - prezent
• Loc de muncă	Universitatea Tehnica din Cluj-Napoca, Romania
• Profesia	Inginer
• Ocupaţia	Sef Lucrări
• Activitatea principală	Activitati de cercetare in domeniul controlului automat.

• Data	2016 - 2021
• Loc de muncă	P3Digital Services
• Ocupaţia	Inginer software
• Activitatea principală	Servicii de consultanta, dezvoltarea aplicatiilor mobile

EDUCAŢIE ŞI STUDII DE CALIFICARE

• Anul	2022
• Numele si tipul organizaţiei	Ghent University, Belgium
• Titlul obţinut	Doctor inginer
• Specializarea	Inginerie

• Anul	2021
• Numele si tipul organizaţiei	Universitatea Tehnica din Cluj-Napoca, Romania
• Titlul obţinut	Doctor inginer
• Specializarea	Ingineria Sistemelor

• Anul	2017
• Numele si tipul organizaţiei	Universitatea Tehnica din Cluj-Napoca, Romania
• Titlul obţinut	Master
• Specializarea	Conducerea Avansata a Proceselor

• Anul	2015
• Numele si tipul organizaţiei	Universitatea Tehnica din Cluj-Napoca, Romania
• Titlul obţinut	Inginer
• Specializarea	Automatica si informatica aplicata (eng.)

ACTIVITATE DIDACTICĂ	Titular al cursurilor	Programul de studii	Anul
	Echipamente de Automatizare Electrice si Electronice	Automatică şi Informatică Aplicată	III
	Laborator Control Engineering	Automatică şi Informatică Aplicată	III

ACTIVITATE ŞTIINŢIFICĂ

TEME DE CERCETARE

Modelare si control de ordin fractionar
Sisteme biomedicale
Fluide non-Newtoniene

PUBLICAŢII (TOTAL, DIN CARE 5 LUCRĂRI REPREZENTATIVE PUBLICATE)

1. Isabela Birs, Cristina Muresan, Dana Copot, Clara Ionescu, Model Identification and Control of Electromagnetic Actuation in Continuous Casting Process With Improved Quality, IEEE/CAA Journal of Automatica Sinica, vol. 10(1), pp. 1-13, 2023. (factor impact 6.717)
2. Isabela Birs, Ioan Nascu, Clara-Mihaela Ionescu, Cristina Muresan, "Event-based fractional order control", Journal of Advanced Research, vol. 25, pp. 191 – 203, 2020. (factor impact 10.479)
3. Isabela Birs, Cristina Muresa, Ioan Nascu, Clara Ionescu. A Survey of Recent Advances in Fractional Order Control for Time Delay Systems, IEEE Access, vol. 7, no. 1, pp. 30951-30965, 2019. (factor impact 4.098)
4. Isabela Birs, Cristina Muresan, Ovidiu Prodan, Silviu Folea, Clara Ionescu, An Experimental Approach towards Motion Modeling and Control of a Vehicle Transiting a Non-Newtonian Environment, Fractal and Fractional, Vol. 5(3), pp. 104, 2021 (factor impact 3.17)
5. Isabela Birs, Dana Copot, Cristina Muresan, Ioan Nascu, Clara Ionescu. Identification For Control of Suspended Objects In Non-Newtonian Fluids, Fractional Calculus and Applied Analysis, vol. 22, no.5, pp. 1378–1394, 2019 (factor impact 3.514).

GRANTURI, CONTRACTE DE CERCETARE (TOTAL, DIN CARE 5 CONTRACTE REPREZENTATIVE DIN 2011)

Competitia TE 2023 – Locul 9 in domeniul Stiinte Ingineresti, 91.2 puncte, actele de finantare se vor semna in curand, 100 000 eur (director)

PD15/2022 - Control fracționar bazat pe evenimente pentru anestezia generală (director)

PED552/2020 - Simulator sedare pacient pentru dozarea optima si personalizata a medicamentelor in anestezia generala (membru cercetator)

TE143/2020 - Novel Fractional Order Autotuners for Poorly Damped Systems to Ensure Improved Safety and Comfort (membru cercetator)

TE65/2018 - Robust fractional order event-based control for optimised resource allocation in complex cyber-physical closed loop systems (membru cercetator)

PED92/2017 - Prototip scalabil de nanorobot in fluide non-Newtoniene folosind model si control de ordin fractionar (membru cercetator)

BURSE, PREMII, GRANTURI (TOTAL, DIN CARE 5 CONTRACTE REPREZENTATIVE)

Junior Postdoctoral Scholarship 2023 - 2026, Ghent University, Belgium

FWO SB doctoral fellow 2019 - 2022 (proiect MOCONEF, 1S04719N), Ghent University

Locul 2 **Young Author Award Isabela R. Birs**, Mihaela Ghita, Maria Ghita, Dana Copot, Cristina I. Muresan, Clara M. Ionescu “An Interdisciplinary, Low-Cost Methodological Framework for Analyzing Dynamical Material Properties for Control- Related Applications”, Ifac Papersonline, vol. 52, no. 9, Elsevier, 2019, pp. 159–64, premiata in Philadelphia, USA, 2019.

EU-COST Action no. **15225** pentru mobilitate in perioada September 2-16, 2019 la grupul de cercetare condus de Prof. Riccardo Caponneto, University of Catania, Sicily, Italy.

Cluj-Napoca, 22.10.2024 SL.dr.ing. Isabela Birs

Anexa 1

CRITERIILE DE ACORDARE A GRADAȚIEI DE MERIT – RAPORT DE AUTOEVAUARE ASUPRA ACTIVITĂŢII DESFĂȘURATE

Isabela Roxana Bîrs

SECȚIUNEA 1
Realizari raportate in Sistemul Integrat de Evaluare a Activitatilor Didactice, Cercetare si Management (SIMAC)

a) Punctajul total realizat în anul k-1 de raportare in SIMAC: total echivalent **38.5558A** (1A = 10)
Punctaj propus: 385.558

b) Punctajul total realizat în anul k-2 de raportare in SIMAC: total echivalent **47.7596A** (1A = 10)
Punctaj propus: 477.596

c) Punctajul total realizat în anul k-3 de raportare in SIMAC: total echivalent **59.0023A** (1A = 10)
Punctaj propus: 590.023

PUNCTAJ TOTAL SECŢIUNEA 1: 1453.177

SECȚIUNEA 2
Alte realizari in planul activitatii didactice (care nu sunt incluse in sistemul integrat de evaluare SIMAC)

- In anul universitar 2020-2021 am refacut laboratoarele la Control Engineering I și II pentru adaptarea la mediul de predare si evaluare online. De asemenea, am adaptat proiectul la Sisteme de Conducere a Proceselor Continue (SCPC) pentru realizarea proiectului online. O alta propunere de laborator online a fost Lab 6. Adaptoare de la Echipamente de Automatizare Electrice si Electronice (EAEE) dedicat mediului online.
- In anul universitar 2022-2023 am ajutat la propunerea unei noua discipline (Emerging Control Systems for Industry 5.0) care a fost introdusa ca disciplina obligatorie in cadrul liniei de studiu de masterat Cyber Physical Systems (CPS).
- Am dezvoltat si construit un stand experimental pentru modelarea si contolul proceselor in medii non-Newtoniene. Acesta este folosit ca baza experimentala pe plan didactic si de cercetare.
- In timpul pandemiei, anul universitar 2020-2021 am adaptat laboratoare existente si am propus noi laboratoare la disciplina Control Engineering 2 pentru a fi utilizate in mediul online: Lab 6. Internal Model Control on a Vertical Take-off and Landing Platform. Ulterior,

acest laborator se foloseste ca suport pentru predarea strategiilor IMC pe platforma experimentala VTOL.

- Am dezvoltat suportul de laborator pentru Cyber Physical Systems care consta in propunerea de 7 laboratore noi: 1. Introduction into Industry 5.0 and analysis of modern control systems, 2. Implementation of standard auto-tuning methods. Case study: vertical take-off and landing, 3. Analysis and implementation of fractional order control systems using various software tools (FOMCOM, NINTEGER, AFOPI, FLOreS). Matlab simulation. Case study: anesthesia control, 4. Practical implementation and validation of fractional order control systems. Case study: vertical take-off and landing, 5. Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: DC motor control., 6. Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: vertical take-off and landing platform., 7. Event-based implementation of fractional order controllers. Case study: vertical take-off and landing platform.
- Pe toata perioada raportarii 2021-2023, evaluarea facuta de studenti este pozitiva. Feedback-ul primit prin sistemul electronic inegrat al UTCN dovedeste implicarea si profesionalismul in activitatea didactica educationala.
- In perioada 2021-2023 am condus peste 20 lucrari de licenta.
- In anul 2023, am participat la intocmirea documentatiei de acreditare la Satu Mare.
- Am fost secretar la comisii de licenta in 2021, 2022 si 2023.
- Am participat la desfasurarea si corectarea examenelor de admitere.

Anexa 2

Apreciere sintetica asupra activitatii desfasurate in ultimii 3 ani

SECTIUNEA 1 Realizari raportate in Sistemul Integrat de Evaluare a Activitatilor Didactice, Cercetare si Management (SIMAC)	Punctaj declarat	Punctaj acordat
a) Punctajul total realizat în anul k-1 de raportare in SIMAC: total echivalent A (1A = 10)	**385.56**	
b) Punctajul total realizat în anul k-2 de raportare in SIMAC: total echivalent A (1A = 10)	**477.60**	
c) Punctajul total realizat în anul k-3 de raportare in SIMAC: total echivalent A (1A = 10)	**590.02**	
TOTAL SECŢIUNEA 1	**1453.18**	
La aceasta sectiune este obligatoriu un minim cumulat pe cei 3 ani de puncte dupa cum urmeaza: profesor: 36 puncte; conferentiar: 21 puncte; sef lucrari / lector: 15 puncte; asistent: 4,5 puncte.		
SECTIUNEA 2 **Alte realizari in planul activitatii didactice (care nu sunt incluse in sistemul integrat de evaluare SIMAC)**	Punctaj declarat	Punctaj acordat
a) Discipline noi asimilate, corelate cu standardele naționale introduse în planul de învăţământ. **Justificare:** - In anul universitar 2020-2021 am refacut laboratoarele la Control Engineering I şi II pentru adaptarea la mediul de predare si evaluare online. De asemenea, am adaptat proiectul la Sisteme de Conducere a Proceselor Continue (SCPC) pentru realizarea proiectului online. O alta propunere de laborator online a fost Lab 6. Adaptoare de la Echipamente de Automatizare Electrice si Electronice (EAEE) dedicat mediului online. - În anul universitar 2022-2023 am ajutat la propunerea unei noua discipline (Emerging Control Systems for Industry 5.0) care a fost introdusa ca disciplina obligatorie in cadrul liniei de studiu de masterat Cyber Physical Systems (CPS).	20.00	
b) Profesor invitat pentru activitati didactice la universităţi din ţară/ străinătate.		
c) Organizarea unor activităţi cu studenţii (practică în ţară/ străinătate, cursuri de vară, etc.).		
d) Dezvoltarea bazei materiale la nivel departamental în concordanţă cu standardele specifice. **Justificare:** Dezvoltarea si construirea unui stand experimental pentru modelarea si contolul proceselor in medii non-Newtoniene. Acesta a fost folosit ca baza experimentala pe plan didactic si de cercetare.	10.00	
e) Dezvoltarea de noi laboratoare. **Justificare:** - In timpul pandemiei, anul universitar 2020-2021 am adaptat laboratoare existente si am propus noi laboratoare la disciplina Control Engineering 2 pentru a fi utilizate in mediul online: Lab 6. Internal Model Control on a Vertical Take-off and Landing Platform. Ulterior, acest laborator se foloseste ca suport pentru predarea strategiilor IMC pe platforma experimentala VTOL. - Am dezvoltat suportul de laborator pentru Cyber Physical Systems care consta in propunerea de 7 laboratore noi: 1. Introduction into Industry 5.0 and analysis of modern control systems, 2. Implementation of standard auto-tuning methods. Case study: vertical take-off and landing, 3. Analysis and implementation of fractional order control systems using various software tools (FOMCOM, NINTEGER, AFOPI, FLOreS). Matlab simulation. Case study: anesthesia control, 4. Practical implementation and validation of fractional order control systems. Case study: vertical take-off and landing, 5. Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: DC motor control., 6. Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: vertical take-off and landing platform., 7. Event-based implementation of fractional order controllers. Case study: vertical take-off and landing platform.	20.00	
f) Recunoasteri ale performantelor didactice educationale. Stabilit pe baza evaluarii cadrului didactic. **Justificare:** Pe toata perioada raportarii 2021-2023, evaluarea facuta de studenti este pozitiva. Feedback-ul primit prin sistemul electronic inegrat al UTCN dovedeste implicarea si profesionalismul in activitatea didactica educationala.	20.00	
g) Activităţi de manageriat în procesul de învăţământ (decan de an, tutoriere ECTS,etc.). **Justificare**: Responsabil de an, Automatica romana, seria B, anul 3	20.00	
h) Alte activităţi educaţionale semnificative diferite de cele de la punctele (a - g). **Justificare**: Conducator stiintific pentru lucrari de licenta.	20.00	
TOTAL SECŢIUNEA 2	**110.00**	**0.00**
Obligatoriu minim 40 de puncte cumulat pentru toti cei 3 ani de raportare		

SECTIUNEA 3 **Activităţi manageriale şi administrative în sprijinul procesului didactic, de cercetare-dezvoltare, etc.**	Punctaj declarat	Punctaj acordat
a) Funcţii executive de conducere (punctajul se acorda pentru ultimii 3 ani):		
1) Rector		
2) Prorector		
3) Decan		
4) Prodecan		
5) Director de departament		
b) Functii deliberative de conducere:		
1) Presedinte al senatului		
2) Vicepreşedinte al senatului		
3) Cancelar al senatului		
4) Alte functii de conducere asociate activitatilor desfasurate in interiorul institutiei.		
TOTAL SECŢIUNEA 3	**0.00**	**0.00**

SECTIUNEA 4 **Activităţi la nivel de departament / facultate care nu sunt incluse in sectiunile anterioare**	Punctaj declarat	Punctaj acordat
a) Activitatea de intocmire a documentatiei de acreditare **Justificare**: In anul 2023, am participat la intocmirea documentatiei de acreditare la Satu Mare.	20.00	
b) Activitatea de intocmire a statelor de functii si a orarului		
c) Activitatea de promovare, pregatirea, desfasurarea admiterii la licenta, masterat **Justificare:** - Secretar la comisii de licenta in 2021, 2022 si 2023. - Supraveghere la examenele de admitere	20.00	
d) Activitatea in cadrul cercurilor stiintifice studentesti altele decat cele definite la S3-h		
e) Organizarea zilei absolventilor, ziua portilor deschise a facultatii		
f) Organizarea concursurilor studentesti locale, nationale si internationale		
g) Tinuta morala si comportarea academica **Justificare**: Conduita morala deosebita si abilitati de comunicare eficiente.	20.00	
h) Alte activitati semnificative la nivel de departament/facultate diferite de cele de la punctele (a-h)		
TOTAL SECŢIUNEA 4	**60.00**	**0.00**

OBSERVATII:

a) Punctajul de la sectiunea 2 este confirmat de catre directorul de departament. Se accentueaza ca punctajul acordat trebuie sa fie intre 0 si punctajul maxim, nuantat in strict acord cu performantele realizate in cei 3 ani de raportare.

b) Punctajul de la sectiunea 3 este acordat de catre directorul de departament din care provine candidatul, calculat pe durata ultimilor 3 ani pentru toate functiile detinute.

c) Punctajul de la secțiunea 4 este atribuit integral de către directorul de departament, cu acordul consiliului de departament.
Punctajul acordat trebuie sa fie intre 0 si punctajul maxim, nuantat in strict acord cu performantele realizate in cei 3 ani de raportare.

DECAN
Prof. Dr. Ing. Vlad Muresan

DIRECTOR DEPARTAMENT
Prof. Dr. Ing. Honoriu Valean

Verificat

Director Direcția pentru
Managementul Cercetării, Dezvoltării și Inovării

Prof. dr. ing. Ovidiu Nemeș

Centralizator punctaje SIMAC

de la începutul anului 2021, până la finalul anului 2023

Nume: **Birs Isabela Roxana**

Grad didactic: **șef lucrări**

Facultate: **Facultatea de Automatică și Calculatoare**

Departament: **Automatică**

An	Activitate didactică [A]	Activitate de cercetare [A]	TOTAL [A]
2021	0.0	38.5558	38.5558
2022	0.0	47.7596	47.7596
2023	0.0	59.0023	59.0023
TOTAL			145.3177
MEDIA			**48.43923**

Data:

Nume: **șef lucrări Birs Isabela Roxana**

Semnătură:

____

Laboratory no.2.
Digital controller tuning using „via s" methods

Laboratory scope:

- Tuning digital controllers using "via s" methods for single-input-single-output processes,
- Closed loop performance evaluation,
- Comparisons between analog and digital control, according to sampling period selection
- Computation of the control signal recurrence relation

Theoretical background:

Tuning digital controllers may be achieved using two methods: a direct approach and an indirect approach. In the Indirect approach, the tuning of the controllers is achieved in the continuous domain ("via s" methods); discretization methods are further applied to the continuous controller in order to obtain the final digital controller.

The schematic representations of the closed loop system with an analog and a digital controller are given in Figures 2.1 and 2.2, respectively.

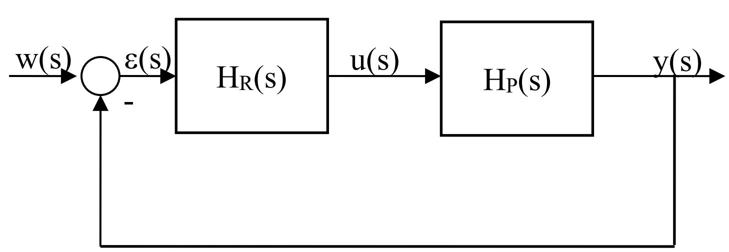


Fig. 2.1. Closed loop representation of a continuous time automatic control system

where $H_P(s)$ – the process; $H_R(s)$ – the continuous-time controller; w- the reference signal; u(s) – the control signal (process input); y(s) – the process (measured) output and ε(s) – the error signal.

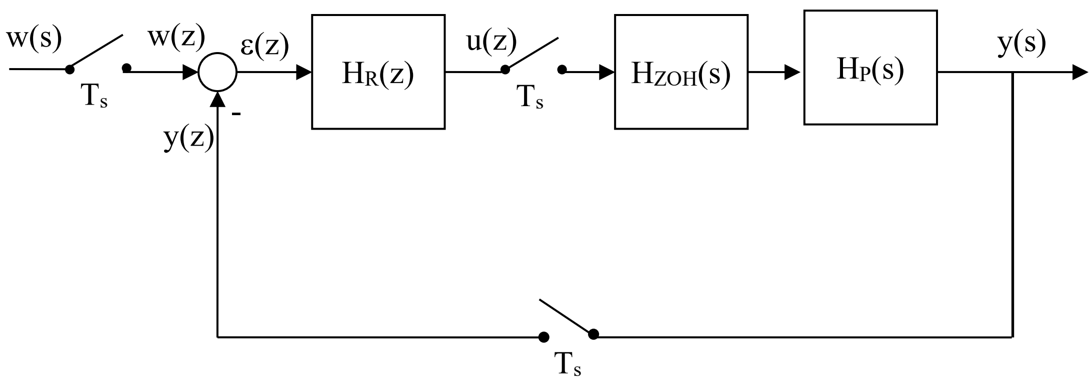


Fig. 2.2. Closed loop representation of a discrete time automatic control

The classical approach towards tuning the controller is based on the schematic representation in Fig. 2.1. The $H_R(s)$ controller is tuned using traditional control methods derived from a specified set of performance criteria. One a PID (or similar) analog controller is obtained, different discretization methods may be used to derive the digital form of the PID controller.

Using the analog PID controller transfer function:

$$H_R(s) = V_R\left[1 + T_d \cdot s + \frac{1}{T_i \cdot s}\right] = \frac{u(s)}{\varepsilon(s)}$$

its discrete-time equivalent may be computed using zero-order-hold method, Tustin bilinear transformation, etc.

Using, for example, the bilinear transformation $\left(s = \frac{2}{T_E} \cdot \frac{1 - z^{-1}}{1 + z^{-1}}\right)$, the following digital equivalent of the PID controller is obtained:

$$H_R(z) = V_R\left[1 + \frac{2T_d}{T_E} \cdot \frac{1 - z^{-1}}{1 + z^{-1}} + \frac{T_E}{2T_i} \cdot \frac{1 + z^{-1}}{1 - z^{-1}}\right] = \frac{1}{1 - z^{-1}} \cdot \left(b_0 + b_1 \cdot z^{-1} + b_2 \cdot z^{-2}\right)$$

where $b_0 = V_R\left(1 + \frac{T_E}{2T_i} + \frac{T_d}{T_E}\right)$, $b_1 = V_R \cdot \left(\frac{T_E}{2T_i} - 1 - \frac{2T_d}{T_E}\right)$ and $b_2 = V_R \cdot \frac{T_d}{T_E}$.

Once the digital form of the controller is available, the control signal recurrence relation may be computed:

$$H_R(z) = \frac{u(z)}{\varepsilon(z)} = \frac{b_0 + b_1 z^{-1} + b_2 z^{-2}}{1 - z^{-1}}$$

$$u(z) - u(z)z^{-1} = b_0 \cdot \varepsilon(z) + b_1 \cdot z^{-1}\varepsilon(z) + b_2 \cdot z^{-2}\varepsilon(z)$$

$$u(k) = u(k-1) + b_0 \cdot \varepsilon(k) + b_1 \cdot \varepsilon(k-1) + b_2 \cdot \varepsilon(k-2)$$

The final relation may be implemented on microcontrollers, PLC tragets, FPGAs (Field Programmable Gate Arrays), process computers, etc.

The hardware-in-the-loop configuration assumes that the digital controller is implemented on a process computer, while the actual real life process is a simulation performed on a personal computer. The aim of the hardware-in-the-loop simulation is to test the implementation of the digital controller on an actual hardware device that would eventually be used to control the real life process. To perform the hardware-in-the-loop simulation, the process will be implemented on a personal computer in Simulink, Matlab, while the digital controller will run on a microcontroller. An example of a microcontroller implementation of the digital algorithm, as well as the associated Simulink diagram of the process and the closed loop configuration are given in the Annex.

Exercises

For the process transfer function:

$$H_P(s) = \frac{2}{(s+1)\cdot(10s+1)} \cdot e^{-s}$$

solve the following problems:

a) Tune a PI and a PD controller for the process that ensures a phase margin of $\gamma_k = 60^o$

b) Select a proper sampling period and obtain the digital controller using zero-order-hold method

c) Design the Simulink block diagram of the closed loop system with the analog PI controller and simulate the output response to a step change in the reference signal w

d) Design the Simulink block diagram of the closed loop system with the digital controller and simulate the output response to a step change in the reference signal w

e) Compare the performance of the two controllers in terms of overshoot and settling time

f) Redesign the digital controller (by choosing a different sampling period) and evaluate the closed loop performance results

g) For the final digital controller, determine the control signal recurrence relation

Solution

a) Let's tune together the PI controller. More information regarding frequency domain tuning can be found in Laboratory 9 from Control Engineering I.

Since the tuning is done in the frequency domain, we should map the process' transfer function from the Laplace domain to the frequency domain. This is done by replacing $s = j\omega$, where j is the imaginary unit and ω is the frequency. Hence, we obtain

$$H_P(s) = \frac{2}{(s+1)\cdot(10s+1)} \cdot e^{-s} = \frac{2}{(j\omega+1)(10j\omega+1)} e^{-s} \quad (1)$$

The transfer function of the PI controller is given by

$$H_c = k_p\left(1 + \frac{1}{T_i s}\right) \quad (2)$$

where k_p is the proportional gain and T_i is the integral time constant. In order to determine the PI controller, we must find the values of k_p and T_i.

Knowing the phase margin constraint $\gamma_k = 60^o$, we can write the phase margin equation as

$$\angle H_{ol}(j\omega_c) = -180^\circ + \gamma_k \tag{3}$$

Note that $\angle H_{ol}(j\omega_c) = \angle\left(H_p(j\omega_c)H_c(j\omega_c)\right) = \angle H_p(j\omega_c) + \angle H_c(j\omega_c)$. The ω_c symbol represents the gain crossover frequency (the frequency at which the magnitude of $H_{ol}(j\omega_c)$ is 1, or 0^{dB}).

Let's assume that $\angle H_c(j\omega_c) = -15^\circ$ (see CE1 lectures for more info). This leads to $|H_{ol}(j\omega_c)| \cong k_p$ and $T_i = \frac{4}{\omega_c}$.

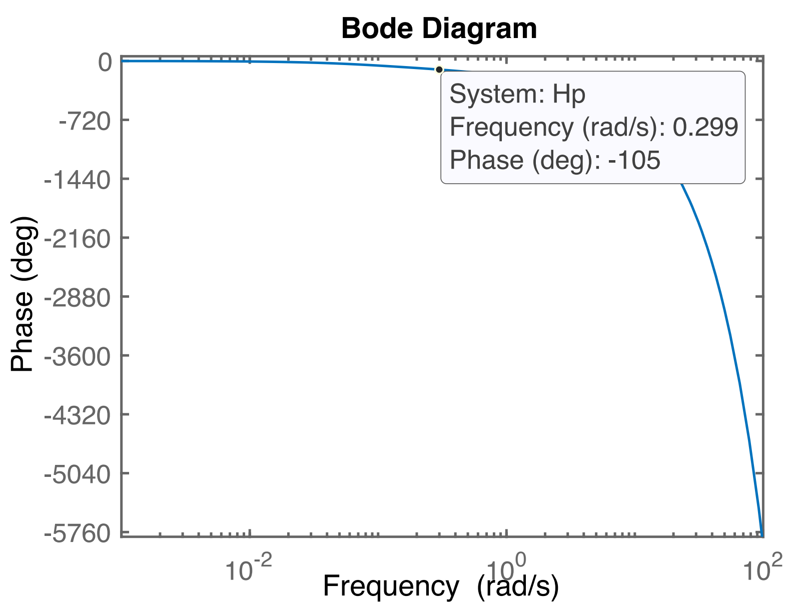
Replacing the phase value of $\angle H_c(j\omega_c)$ in (3) gives

$$\angle H_p(j\omega_c) = -180^\circ + 15^\circ + \gamma_k = -165^\circ + \gamma_k \tag{4}$$

For our transfer function and our imposed phase margin $\gamma_k = 60^o$, $\angle H_p(j\omega_c)$ is obtained as $\angle H_p(j\omega_c) = -165^\circ + 60^\circ = -105^\circ$. Now we can determine ω_c, either analytically or from the Bode diagram plot (because we know $H_p(j\omega_c)$, hence we know how the phase is going to look like). Let's do it from the Bode plot, for simplicity. In MatLAB, we declare the process' transfer function and we do a quick Bode. Then, we look on the Bode phase plot and read the frequency at which the phase is equal to -105°.

```
Hp = tf(2, [10 11 1], 'IODelay', 1);
bode(Hp)
```

Don't forget the time delay!



Now we know that $\omega_c = 0.299 rad/s$. We can now compute T_i as

$$T_i = \frac{4}{\omega_c} = \frac{4}{0.299} => T_i = 13.3779 \quad (5)$$

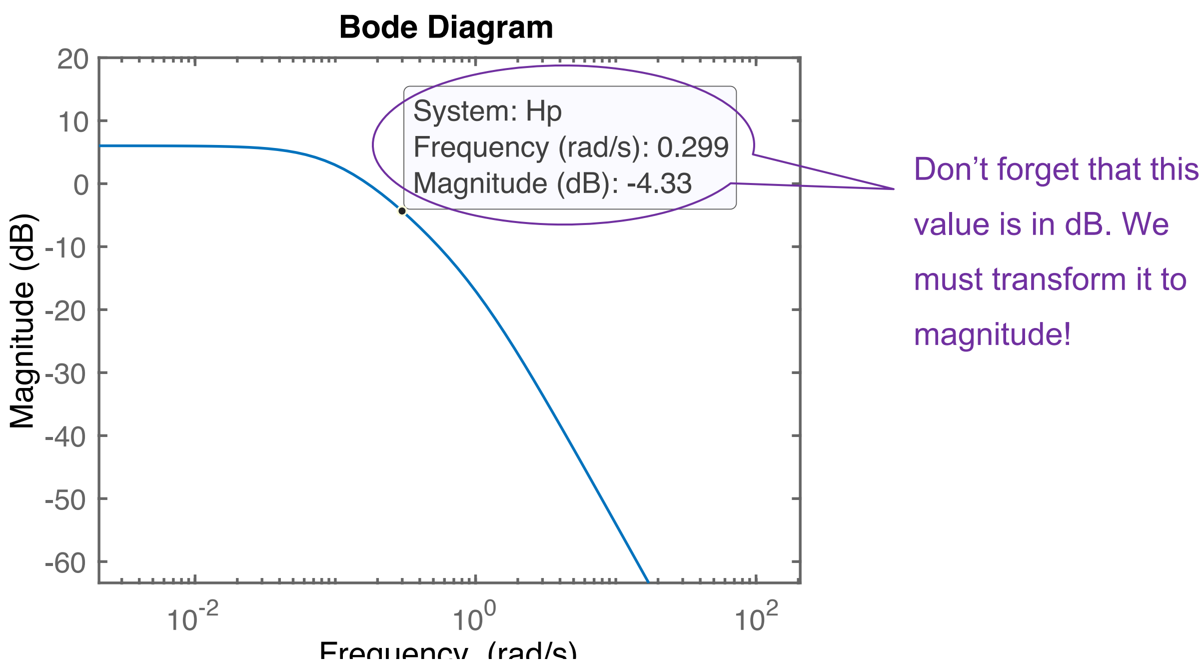
We also know that the magnitude of the open loop system at the crossover frequency is 1 (or 0^{dB}). Mathematically, this can be written as

$$|H_{ol}(j\omega_c)| = |H_c(j\omega_c)| \cdot |H_p(j\omega_c)| = 1 \quad (6)$$

We know that $|H_c(j\omega_c)| = k_p$, hence we have $k_p \cdot |H_p(j\omega_c)| = 1$, from where we obtain

$$k_p = \frac{1}{|H_p(j\omega_c)|} \quad (7)$$

The magnitude of $|H_p(j\omega_c)|$ can be read from the H_p Bode diagram, this time looking at the magnitude plot (just find the magnitude of H_p for the $\omega_c = 0.282$rad/s frequency.



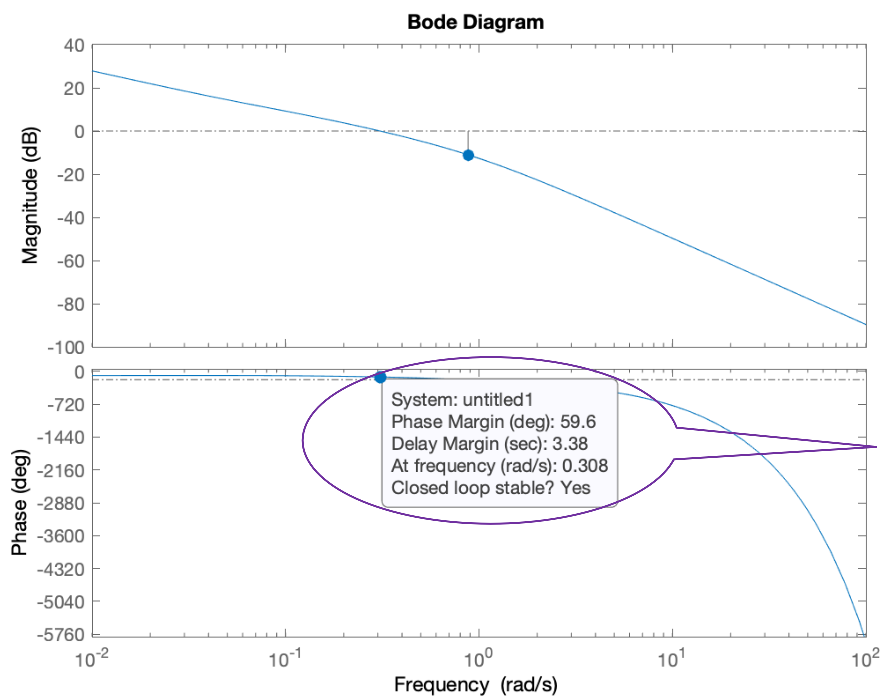
In order to obtain k_p, we must transform from dB to magnitude. We can use the MatLAB function db2mag(-4.33) that gives $|H_p(j\omega_c)|$ =0.6074 and finally we obtain

$$k_p = \frac{1}{|H_p(j\omega_c)|} = \frac{1}{0.6074} => k_p = 1.6463 \quad (8)$$

We now have the PI controller

$$H_c = 1.6463\left(1 + \frac{1}{13.3779\,s}\right) \tag{9}$$

If all the computations are correct, we should now have an open loop system that has a phase margin of γ_k = 60°. Checking this in MatLAB (just draw a Bode plot of the open loop system -> Hc*Hp) gives



Don't know how to see this? Right click on the Bode plot, Characteristics -> Minimum Stability Margins

The phase margin is close to what we have imposed!

We have successfully obtained the PI controller. But what happens further?

b) We have tuned the controller using "via s" methods. If this were for a real-life process, we can implement it in its discrete form.

In order to do this, we compute the discrete-time equivalent using the 'zoh' transform. Don't forget to choose a sampling time that respects Shannon's theorem (the sampling time should be at least 2 times smaller, than the smallest time constant). In order to find for the smallest time constant, we should look at both the controller and the process. Note that the time delay should alse be considered!

Don't forget me!

$$H_P(s) = \frac{2}{(s+1)\cdot(10s+1)}\cdot e^{-s} \qquad H_c = 1.6463\left(1+\frac{1}{13.3779\,s}\right) = \frac{22.02\,s + 1.646}{13.38\,s}$$

Which one is the smallest?

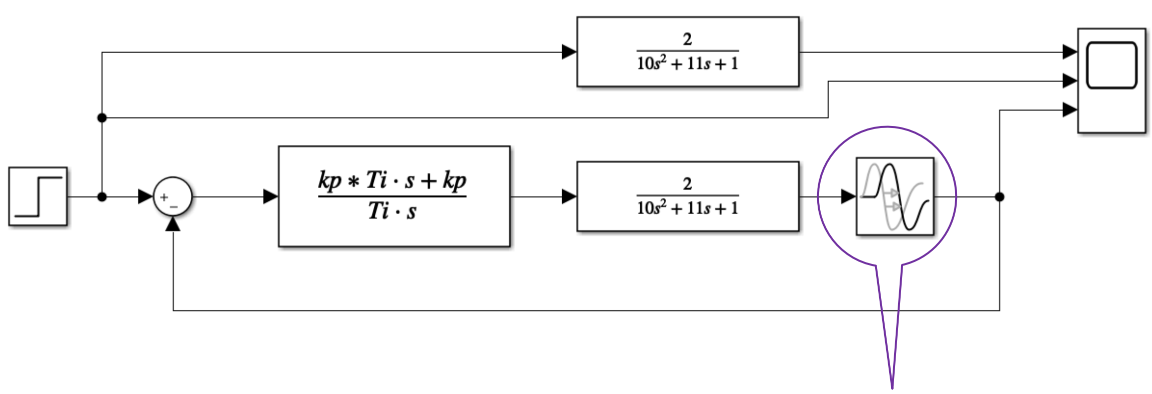
The smallest time constant is 1 s. Hence, the maximum sampling time T_s=0.5 s. Discretize the controller using Matlab.

```
kp = 1.6463; Ti = 13.3779;
Hc = tf([kp*Ti  kp], [Ti 0]);

Ts = 0.5;
Hc_d = c2d(Hc, Ts, 'zoh')
```

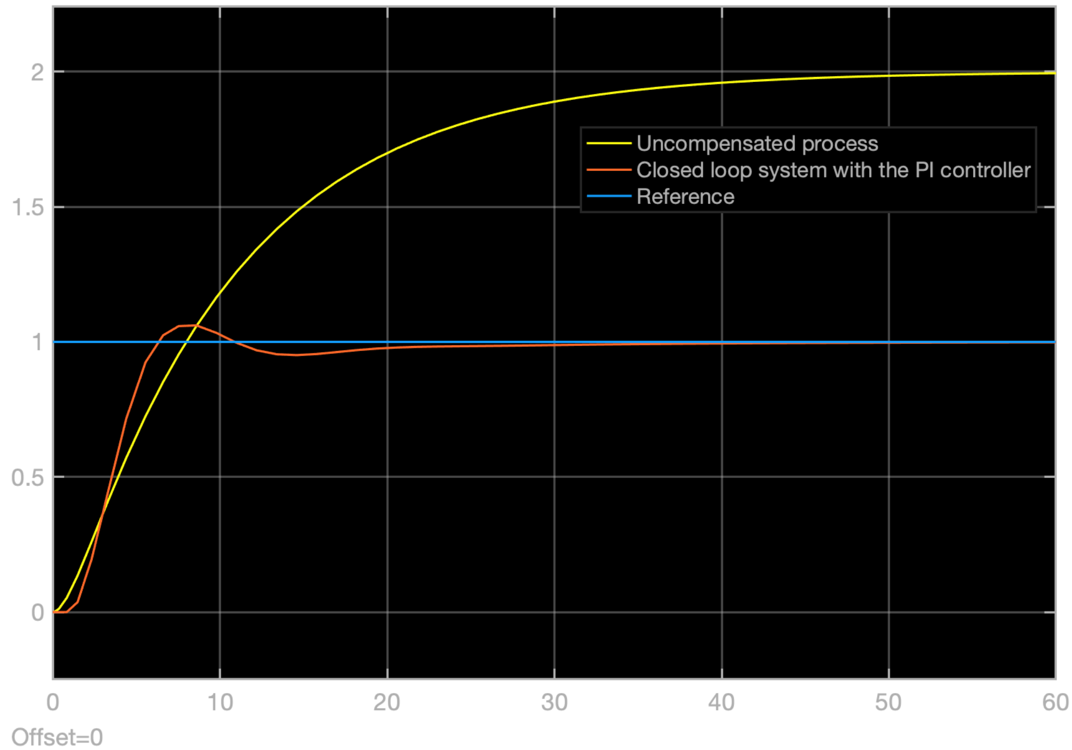
$$H_{c\_d}(z^{-1}) = \frac{1.646\,z - 1.585}{z-1} = \frac{1.646 - 1.585z^{-1}}{1-z^{-1}}$$

c) Let's draw a Simulink Block Diagram in order to see how the continuous PI performs. (Do you remember how to open Simulink? Just write "simulink" into Matlab's command window. Draw the block diagram below. Note that the Scope block has 3 inputs. On the first one, we will see the step response of the uncompensated system (just the system, no controller added). On the second one, we want to see the step reference. The last scope input is the closed loop system response with the continuous-time PI controller.

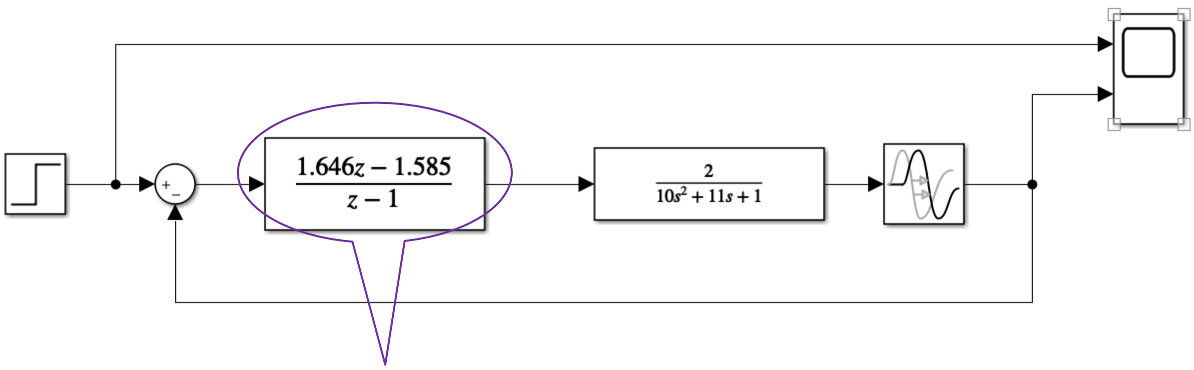


This block is called "**Transport Delay**". We use it to simulate the time delay. After dragging it to your model, double click on it and set Time Delay:1. (!Note that the values inserted are positive)

After the simulation is performed, the scope should look like this. Note that the output of the closed loop system goes to the reference value of 1.

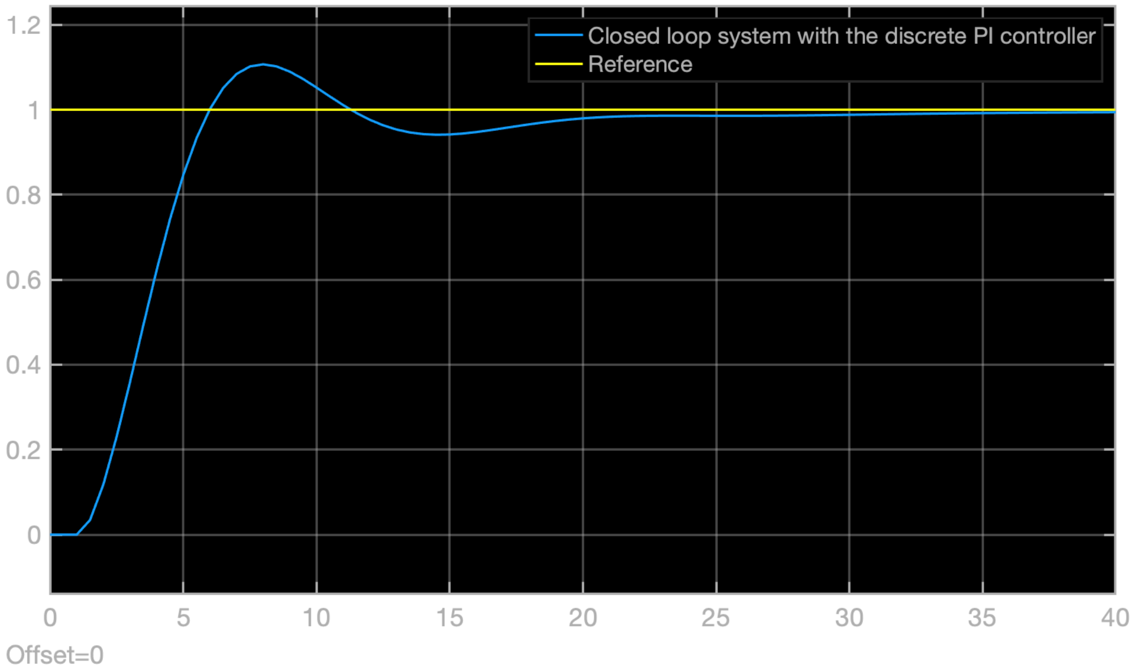


d) Furthermore, we should simulate the closed loop system response with the discrete controller. The block diagram is the same, the only exception being the "Discrete Transfer Fcn" block that replaces the continuous "Transfer Fcn".

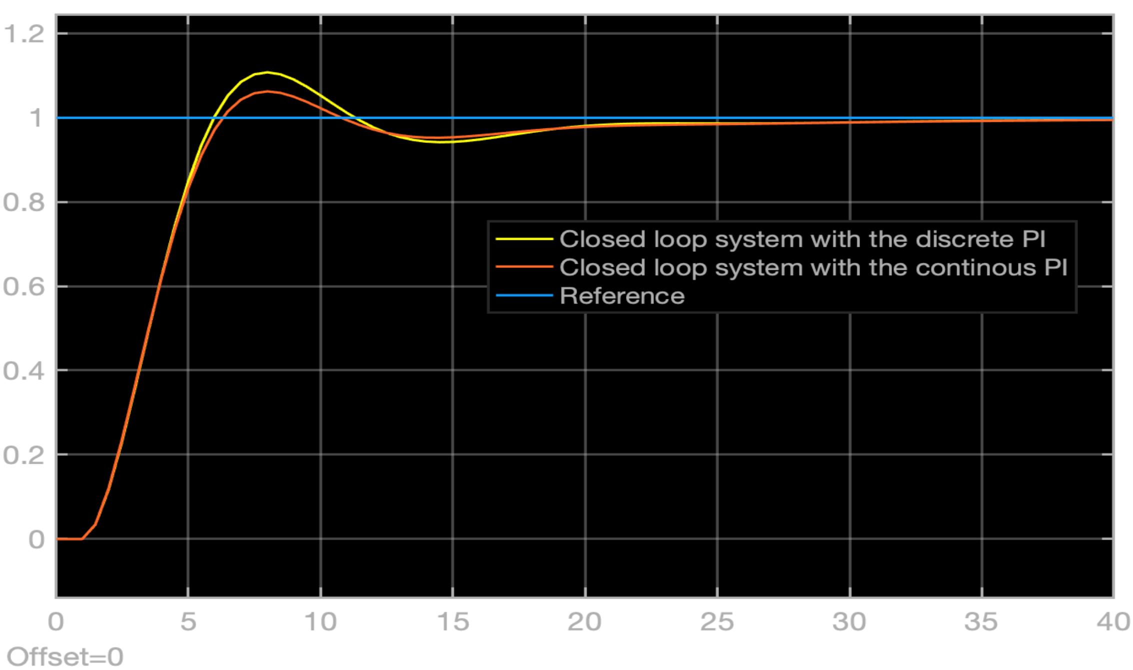


This is the **Discrete Transfer Fcn** block. Double click on it, set the numerator and the denominator and **also the sampling time**.

The response should look like this.



e) Putting the response of the closed loop system with both the continuous and the discrete PI controllers on the same plot results in the following figure.



The two responses are similar. The difference in the performance is given by the sampling time choice. Choosing a smaller sampling time should result in a better performance.

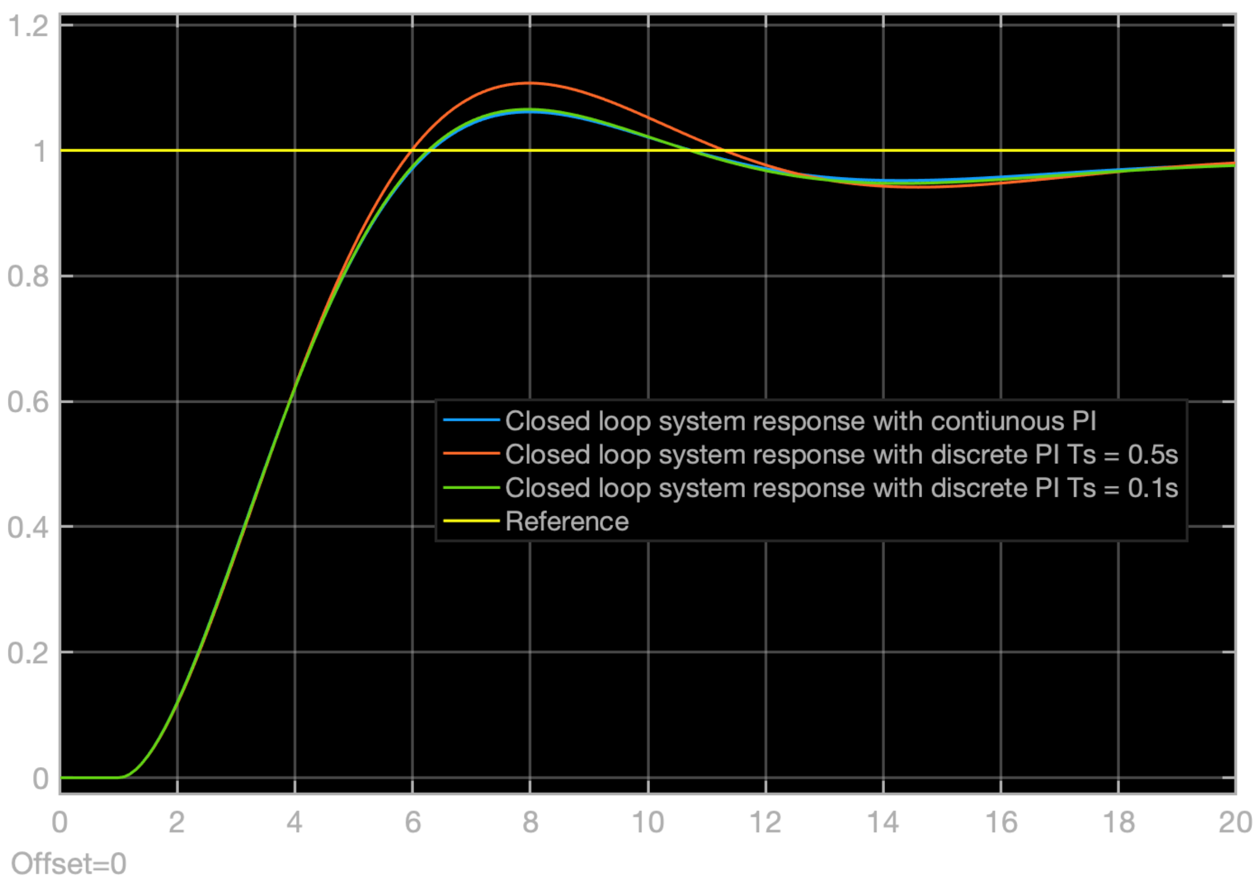
f) We redesign the controller using a smaller sampling time. For example, 0.1

```
kp = 1.6463; Ti = 13.3779;
Hc = tf([kp*Ti  kp], [Ti 0]);

Ts = 0.1;
Hc_d = c2d(Hc, Ts, 'zoh')
```

$$\Rightarrow H_{c\_d}(z^{-1}) = \frac{1.646\,\mathrm{z} - 1.634}{\mathrm{z} - 1} = \frac{1.646 - 1.634z^{-1}}{1 - z^{-1}}$$

Now we should go back in the block diagram and update the discrete time controller parameters **as well as the sampling time** in the "Discrete Transfer Fcn" block. A zoomed response in the [0, 20]s time interval should look like this:



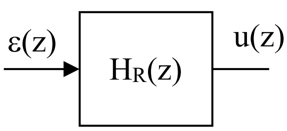
Please observe how similar are the responses with the discrete PI with the sampling time of 0.1 and the continuous response.

You did all the block diagrams, but you're not seeing the correct responses? Here are some common mistakes:

- *You should use the "Transport Delay" block and not the "Variable Transport Delay" one*
- *The correct time delay amount is set in the "Transport Delay" block*
- *All your nominators and denominators are correct*
- *The "Discrete Transfer Fcn" block has the sampling time set properly (you shouldn't leave the default -1 value)*
- *Once again,check that every discrete "Discrete Transfer Fcn" has the sampling time for which those num and den were obtained!*
- *Make sure that you use negative feedback and not positive one (the round sum block should have a plus and a minus)*

g) For real life digital implementations, the recurrence formula should be computed.This gives a formula that allows the computation of the command signal at the present moment, denoted by u(k).

Remember that



From here we can write $H_R(z) = \frac{u(z)}{\varepsilon(z)}$.

Taking the PI controller we can rewrite the previous equation as $\frac{1.646 - 1.585z^{-1}}{1 - z^{-1}} = \frac{u(z)}{\varepsilon(z)}$.

Performing diagonal multiplication gives

$$1.646\varepsilon(z) - 1.585z^{-1}\varepsilon(z) = u(z) - z^{-1}u(z)$$
$$u(z) = 1.646\varepsilon(z) - 1.585z^{-1}\varepsilon(z) + z^{-1}u(z)$$
$$u(k) = 1.646\varepsilon(k) - 1.585\varepsilon(k-1) + u(k-1)$$

Current error Previous error Previous command

Homework:

Repeat all the points above for the PD controller given by

$$H_c(s) = k_p \frac{1+\tau_d s}{1+\beta\tau_d s}, \quad \beta \in (0.1, 0.125)$$

Some brief tuning steps of the PD controller:

1. $\angle H_{ol}(j\omega_c) = -180^\circ + \gamma_k$
2. $choose \angle H_c(j\omega_c)$ maximum

   $$\angle H_c(j\omega_c) = atan\frac{1-\beta}{2\sqrt{\beta}}$$

   $$\omega_c = \frac{1}{\tau_d\sqrt{\beta}}$$

$$|H_c(j\omega_c)| = \frac{k_p}{\sqrt{\beta}}$$

3. select $\beta \in (0.1, 0.125)$ => $\angle H_c(j\omega_c)$ = ?
4. $\angle H_{ol}(j\omega_c) = \angle\left(H_p(j\omega_c)H_c(j\omega_c)\right) = \angle H_p(j\omega_c) + \angle H_c(j\omega_c)$

   $\angle H_p(j\omega_c) = -180^\circ - \angle H_c(j\omega_c) + \gamma_k$ => ω_c= ? (read it from Bode)
5. $\tau_d = \frac{1}{\omega_c\sqrt{\beta}}$
6. $|H_{ol}(j\omega_c)| = |H_c(j\omega_c)| \cdot |H_p(j\omega_c)| = 1$

   $\frac{k_p}{\sqrt{\beta}} \cdot |H_p(j\omega_c)| = 1$ (read $|H_p(j\omega_c)|$ from Bode)

   $$k_p = \frac{\sqrt{\beta}}{|H_p(j\omega_c)|}$$

Laboratory no.6.

Internal Model Control on a Vertical Take-Off and Landing platform

Description of the experimental unit

The parts comprising the VTOL are emphasized in Fig 1. The main part is the cantilever beam which is fixed to the base platform through a rotating rod. The beam is equipped with a counterweight (left) and a variable speed fan (right). The fixing point is placed near the counterweight at 1/3 of the length of the total beam. The input of the system is considered the voltage applied to the variable speed fan. This causes the fan to rotate and generates thrust in order to move the beam upward. The measurements consider a fixed imaginary axis perpendicular to the base platform and an axis through the middle of the beam. The pitch is measured as the angle between the two axes. The 0° position is considered when the two axes are perpendicular. The physical construction of the platform allows movements in the interval $[-23, 60]^{\circ}$, while the maximum input voltage belongs to the [0,10]V interval.

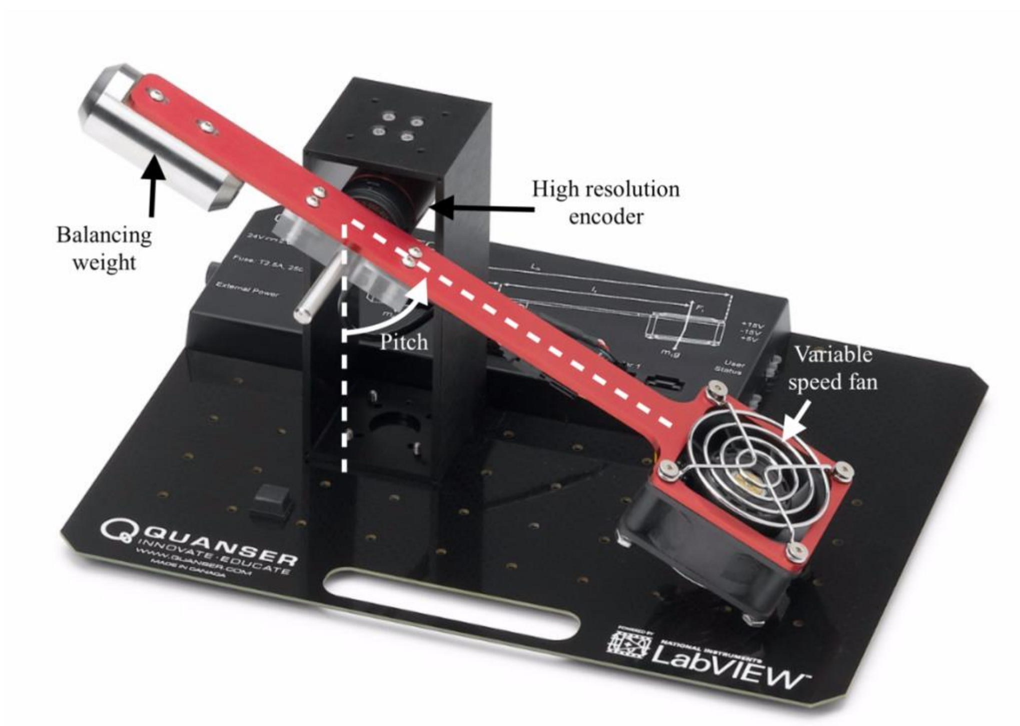


Fig. 1. VTOL platform

The process is highly nonlinear, as shown in Fig.2.

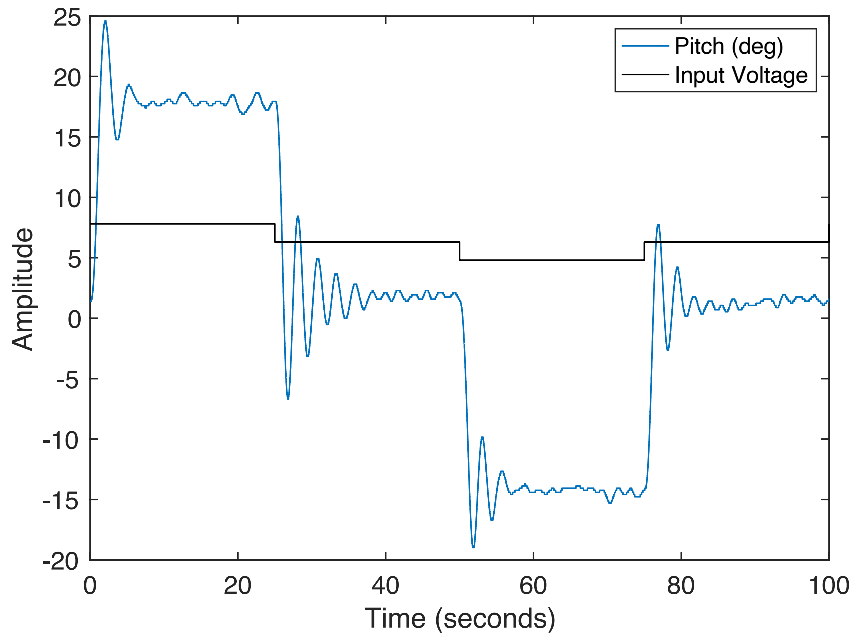


Fig. 2. Different experiments on the VTOL platform

Task 1: What causes the nonlinear nature of the process? (Discuss based on Fig. 1)

The dataset is given in "exp_vtol.mat". Load the dataset file in Matlab and plot the response of the VTOL (y) to the input (u) on the period of time (t).

Note that the step input value is 6.3V and that the experimental data has been collected with a sampling rate Ts=0.005s.

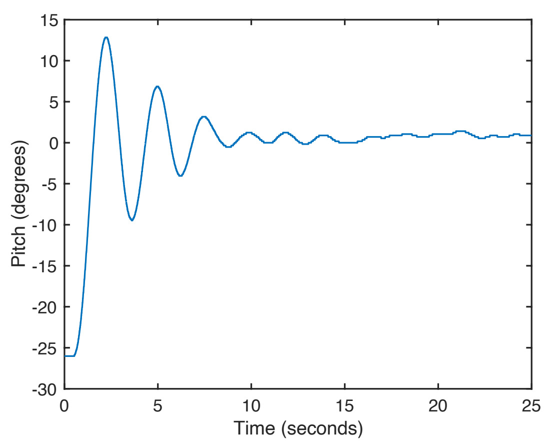


Fig. 3. Experimental data

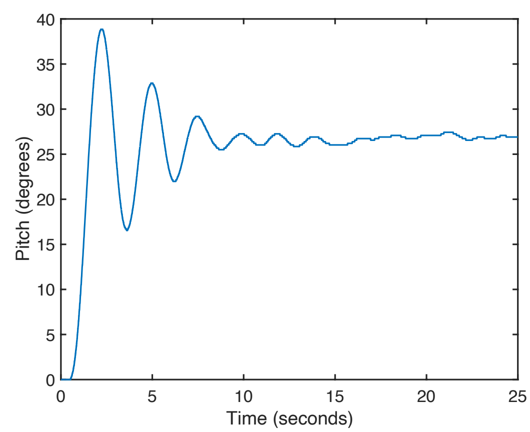


Fig. 4. Normalized experimental data

The identified transfer function for the VTOL platform is

$$\boldsymbol{H(s)} = \frac{Y(s)}{U(s)} = \frac{\mathbf{22.24}}{\boldsymbol{s^2 + 0.6934s + 5.244}} \boldsymbol{e^{-0.8s}}$$

Task 2: Plot the experimental data (using plot(t,y)), as well as the step response of H(s) on the same figure to evaluate how well your model approximates the dynamics in the experimental data. To plot the step response of H(s) do not forget that the input signal has to be the same as in the experimental data. Additionally, the time scale has to be the same.

Task 3: Design an IMC controller for the VTOL process

3. 1. Approximate the time delay using the Padé approximation $e^{-\tau s} = \frac{1-\frac{\tau}{2}s}{1+\frac{\tau}{2}s}$. Determine the new process model $\hat{P}(s)$ with the approximated time delay.

3.2. Break the process model $\hat{P}(s)$ into a good part $\widehat{P_g}(s)$ and a bad part $\widehat{P_b}(s)$ such that $\widehat{P_b}(0) = 1$.

3.3. Compute $\widehat{P_g^{-1}}(s)$.

3.4. Choose $F(s) = \frac{1}{(\lambda s+1)^n}$ such that the IMC controller $C(s) = \widehat{P_g^{-1}}(s)$ F(s) is a semi-proper transfer function and $\lambda = 1$.

3.5. Compute the equivalent controller $R(s) = \frac{\widehat{P_g^{-1}}(s)\,\mathrm{F(s)}}{1-\widehat{P_g^{-1}}(s)\,\mathrm{F(s)}\hat{P}(s)}$

3.6. Compute the closed loop system $H_0(s) = \frac{R(s)H(s)}{1+R(s)H(S)}$. Simulate the response of the closed loop system to a step reference of 20°.

3.7. Readjust the value of λ such that the settling time is less than 6s.

3.8. Discretize the equivalent controller using a correct sampling time and implement the closed loop system with the discrete-time controller in Simulink.

3.9. Compare the closed loop responses obtained with the continuous-time and discrete-time controllers. Plot the control signal for both cases and saturate it (remember that the control value can be between [0, 10] V).

3.10. Introduce an output step disturbance of 5^0 at time t = 10s. How is the disturbance handled by the closed loop system?

3.11. Slightly alter the proportional gain of the transfer function of the process (change the value of k_p by 5%-20%). Analyze the robustness of the closed loop system. What is the settling time in this case?

3.Why is robustness important for Vertical Take-Off and Landing Platforms?

SYLLABUS

1. Data about the program of study

1.1	Institution	The Technical University of Cluj-Napoca
1.2	Faculty	Faculty of Automation and Computer Science
1.3	Department	Automation
1.4	Field of study	Systems Engineering
1.5	Cycle of study	Research Masters
1.6	Program of study/Qualification	CYBER PHYSICAL SYSTEMS
1.7	Form of education	Full time
1.8	Subject code	16.10

2. Data about the subject

2.1	Subject name			Emerging Control Systems for Industry 5.0			
2.2	Subject area						
2.2	Course responsible/lecturer			Prof.Dr.Ing. Cristina I. Muresan – cristina.muresan@aut.utcluj.ro			
2.3	Teachers in charge of seminars			Sl. Dr. Ing. Isabela Birs – isabela.birs@aut.uctluj.ro			
2.4 Year of study	2	2.5 Semester	2	2.6 Assessment	E		
2.7 Subject category	Formative category						DA
	Optionality						DO

3. Estimated total time

3.1 Number of hours per week	3	of which	3.2 Course	2	3.3 Seminar		3.3 Laborator	1	3.3 Proiect		
3.4 Total hours in the curriculum	42	of which	3.5 Course	28	3.6 Seminar		3.6 Laborator	14	3.6 Proiect		

3.7 Individual study:	
(a) Manual, lecture material and notes, bibliography	23
(b) Supplementary study in the library, online and in the field	10
(c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays	10
(d) Tutoring	2
(e) Exams and tests	3
(f) Other activities	

3.8 Total hours of individual study (summ (3.7(a)…3.7(f)))	58
3.9 Total hours per semester (3.4+3.8)	100
3.10 Number of credit points	4

4. Pre-requisites (where appropriate)

4.1	Curriculum	System Theory I+II, Control Engineering I+II
4.2	Competence	Fundamental knowledge of automation

5. Requirements (where appropriate)

5.1	For the course	Bibliography reading for lectures
5.2	For the applications	Laboratory classes are compulsory

6. Specific competences

Professional competences	C4. Analysis, synthesis and implementation of advanced control startegies with practical applications C4.1 Performance criteria for advanced process control methods C4.2 Use of interdisciplinary and multidisciplinary knowledge and information to integrate advanced process control methods in an industrial setting C4.3 Creative use of principles and advanced methods to ensure safety, security and employment of advanced process control methods C4.5 Development of professional or/and interdisciplinary research projects, while meeting quality, security and safety standards
Cross competences	Team work Scientific communication of results

7. Discipline objectives (as results from the *key competences gained*)

7.1	General objective	• Introduction into basic concepts related to fractional order control, autotuning methods and event-based implementations
7.2	Specific objectives	• Industry 5.0 concepts and modernization of control systems • Emerging control methods • Analysis and synthesis of fractional order control strategies • Analysis and synthesis of auto-tuning methods • Event-based implementation possibilities and advantages

8. Contents

8.1. Lecture (syllabus)	Number of hours	Teaching methods	Notes
Introduction: from Industry 1.0 towards Industry 5.0. Industry 4.0 and cyber physical systems. Industry 5.0 and cyber physical cognitive systems (CPGS). Modern control systems.	4	PPT presentations, open discussions, demonstration, case studies	In case of major force classes will be held online using Teams
Emerging control methods suitable for Industry 5.0. Basics of auto-tuning methods	4		
Fractional order control systems: introduction, advantages, tuning, implementation	4		
Fractional order control systems and auto-tuning methods. A time domain approach. Implementation and validation on CPGS	4		

Fractional order control systems and auto-tuning methods. A frequency domain approach. Implementation and validation on CPGS	4		
Fractional order event-based control systems. Increasing the efficiency of control systems by reducing energy use according to the sustainability standards sought by Industry 5.0.	4		
Industrialization of fractional order control systems. Case studies	4		

Bibliography

1. Monje, C.A.; Chen, Y.Q.; Vinagre, B.; Xue, D.; Feliu, V. Fractional Order Systems and Controls: Fundamentals and Applications; Springer: Berlin, Germany, 2010
2. C. Copot, C.M. Ionescu, C.I. Muresan (2020), Image-Based and Fractional-Order Control for Mechatronic Systems. Theory and Applications with MATLAB®, ISBN 978-3-03-042005-5, 978-3-03-042006-2, DOI: 10.1007/978-3-030-42006-2, Springer
3. Cristina I. Muresan, Robin De Keyser, Revisiting Ziegler–Nichols. A fractional order approach, ISA Transactions, 2022,DOI: 10.1016/j.isatra.2022.01.017
4. I. Birs, I. Nascu, C. Ionescu, C. Muresan (2020), "Event-based fractional order PID control", Journal of Advanced Research, Volume 25, pp.191-203, DOI: 10.1016/j.jare.2020.06.024 BURNS Roland S., Advanced control engineering, 2004, Oxford
5. Vilanova, Ramón and Antonio Visioli. "PID control in the Third Millennium: lessons learned and new approaches." (2012).

8.2. Seminars /Laboratory/Project	Number of hours	Teaching methods	Notes
Introduction into Industry 5.0 and analysis of modern control systems	2	Practical use of dedicated equipment, case studies, demonstration, brainstorming	In case of major force classes will be held online using Teams
Implementation of standard auto-tuning methods. Case study: vertical take-off and landing	2		
Analysis and implementation of fractional order control systems using various software tools (FOMCOM, NINTEGER, AFOPI, FLOreS). Matlab simulation. Case study: anesthesia control	2		
Practical implementation and validation of fractional order control systems. Case study: vertical take-off and landing.	2		
Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: DC motor control.	2		
Practical implementation and validation of fractional order control systems and auto-tuning methods. Case study: vertical take-off and landing platform.	2		

Event-based implementation of fractional order controllers. Case study: vertical take-off and landing platform.	2		
Bibliography 1. Tepljakov, Aleksei, et al. “FOMCON Toolbox for Modeling, Design and Implementation of Fractional-Order Control Systems.” Applications in Control, De Gruyter, 2019, pp. 211–36, doi:10.1515/9783110571745-010. 2. Lennart van Duist, Gijs van der Gugten, Daan Toten, Niranjan Saikumar, Hassan HosseinNia, FLOreS - Fractional order loop shaping MATLAB toolbox, IFAC-PapersOnLine, Volume 51, Issue 4, 2018,Pages 545-550, DOI: 10.1016/j.ifacol.2018.06.152. 3. QNET 2.0 VTOL Board for NI ELVIS, Student workbook, Quanser, Ontario, Canada, 2011 4. https://www.mathworks.com			

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

The content of the lectures and laboratory classes corresponds to some of the newest approaches in control engineering. Selected case studies refer to emerging applications, ranging from aerodynamics to biomedical engineering. The content of the lectures and the laboratory classes has been discussed with companies in Romania.

10. Evaluation

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Course	Evaluation of the acquired skills, activity within lectures	Written exam	50%
10.5 Seminars /Laboratory/Project	Evaluation of the practical skills, attendance, activity within laboratory classes	Oral exam	50%
10.6 Minimum standard of performance Exam grade >5, Laboratory grade>5			

Date of filling in:		Title Surname Name	Signature
4.06.2024	Lecturer	Prof. dr.ing. Cristina I. Muresan	
	Teachers in charge of application	SL.dr.ing. Isabela R. Birs	

Date of approval in the department of Automation ________________________	Head of department Prof.dr.ing. Honoriu Valean
Date of approval in the faculty of Automation and Computer Science ________________________	Dean Prof.dr.ing. Mihaela Dinsoreanu

Laboratory Assignment 2: Implementation of Standard Auto-tuning Methods

Case Study: Vertical Take-off and Landing (VTOL) System

1. Objectives

1. To understand and apply standard auto-tuning methods to a time-delay system, specifically a Vertical Take-off and Landing (VTOL) system.

2. To implement and compare the Ziegler-Nichols method and a relay-based autotuning method (KC) for tuning controllers in a simulated environment.

3. To analyze the performance of the tuned controllers using MATLAB and Simulink.

2. Mathematical Formulations

In this section, we will explore the mathematical foundations of two standard auto-tuning methods: Ziegler-Nichols and a relay-based autotuner method (KC). These methods are crucial for tuning controllers in systems with time delays, such as the VTOL system.

2.1 Ziegler-Nichols Method

The Ziegler-Nichols method is a heuristic tuning method that provides a systematic approach to obtaining controller parameters for a given process without the need of a process model. It can be applied to time-delay systems, although the original method does not explicitly consider time delays.

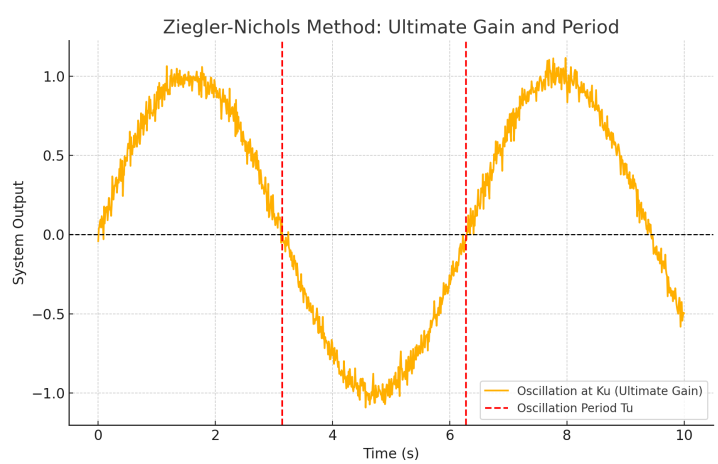


Figure 1. ZN method

The process involves the following steps:

1. Set the I (integral) and D (derivative) gains to zero.

2. Increase the proportional gain (Kp) until the system reaches the ultimate gain (Ku), where the system oscillates with a constant amplitude (see Figure 1).

3. Measure the oscillation period (Tu).

4. Use the following formulas to set the PID controller parameters:

For a PID controller:

- Kp = 0.6 * Ku
- Ti = Tu / 2
- Td = Tu / 8

2.2 Relay-Based Autotuner (KC) Method

The relay-based autotuning method, the KC method, is another approach to determining the PID parameters. This method is particularly useful for systems with time delays.

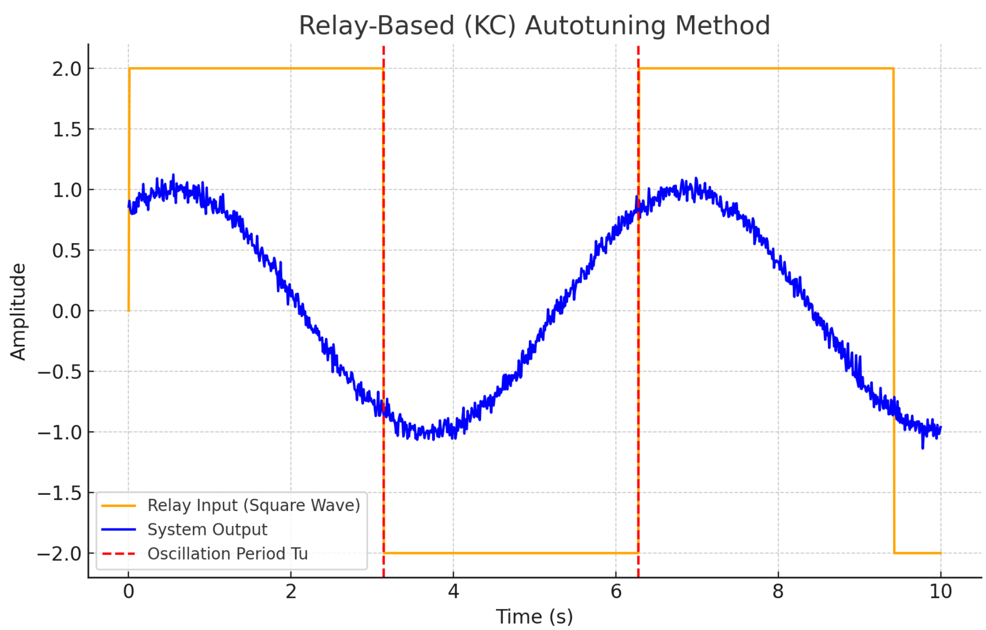


Figure 2. KC method

The key steps include:

1. Implement a relay feedback in the control loop, where the relay introduces a square wave input to the system.

2. The system oscillates in response to the relay input, and the resulting oscillations are used to calculate the ultimate gain (Ku) and the ultimate period (Tu) – see Figure 2.

3. The PID parameters are then calculated using the following formulas:

For a PID controller:

- Kp = 0.45 * Ku
- Ti = Tu / 1.2
- Td = Tu / 4

3. Tasks

1. Simulate the VTOL Process in Simulink:

Develop a Simulink model that accurately represents the VTOL system as a time-delay process. Use the following transfer function to illustrate the process

$$\boldsymbol{H}(\boldsymbol{s}) = \frac{Y(s)}{U(s)} = \frac{\mathbf{22.24}}{\boldsymbol{s}^{2} + \mathbf{0.6934}\boldsymbol{s} + \mathbf{5.244}} \boldsymbol{e}^{-\mathbf{0.8}\boldsymbol{s}}$$

2. Tune Two Controllers Using the Methods Described:

Apply the Ziegler-Nichols method to tune the first controller. Document the process of finding Ku and Tu, and calculate the PID parameters.

Apply the relay-based autotuner (KC method) to tune the second controller. Document the steps taken to implement the relay feedback and the resulting PID parameters.

3. Implement the tuned controllers in Simulink:

Incorporate both tuned controllers into the Simulink model of the VTOL system. Ensure that the controllers are correctly configured and connected to the system.

4. Analyze and Compare the Results:

Run simulations with both controllers and collect data on system performance. Focus on key metrics such as rise time, settling time, overshoot, and stability.

Compare the performance of the two controllers and provide a detailed analysis of which method provides better control for the VTOL system.

Fisa individuala a cadrului didactic

Anul universitar 2021 - 2022; Semestrul 1

Cadru didactic Birs Isabela Roxana
Disciplina Sisteme de conducere a proceselor continue - laborator, proiect
Facultatea Facultatea de Automatica si Calculatoare
Programul de studiu Automatica si Informatica Aplicata-lic
Anul 4 **Semestrul** 1
Departament Automatica
Facultate departament Facultatea de Automatica si Calculatoare

Nr	Aspecte evaluate	T1	T2	Calificativ		N1	Ind1 (%)	N2	Ind2 (%)
1	Cum apreciati modul de predare a cadrului didactic ?	9	9	1	Foarte bun	7	77.78	7	77.78
				2	Bun	2	22.22	2	22.22
				3	Satisfacator	0	-	0	-
				4	Nesatisfacator	0	-	0	-
2	Cum apreciati relatia cadru didactic - student ?	9	9	1	Foarte buna	7	77.78	7	77.78
				2	Buna	2	22.22	2	22.22
				3	Satisfacatoare	0	-	0	-
				4	Nesatisfacatoare	0	-	0	-
3	Cum apreciati calitatea informatiilor transmise, a suportului de curs/aplicatii si/sau a materialelor bibliografice (daca este cazul) ?	8	8	1	Foarte buna	6	75.00	6	75.00
				2	Buna	2	25.00	2	25.00
				3	Satisfacatoare	0	-	0	-
				4	Nesatisfacatoare	0	-	0	-
4	Modalitatea de evaluare a activitatii si cunostintelor a fost corecta si obiectiva ?	9	9	1	Da	8	88.89		
				2	Partial	1	11.11		
				3	Nu	0	-		
				4	Nu am fost evaluat	0	-		
5	Care a fost gradul d-voastra de prezenta la activitatea sustinuta de cadrul didactic ?	9	9	1	0 - 20 %	0	-		
				2	20 - 40 %	1	11.11		
				3	40 - 60 %	0	-		
				4	60 - 80 %	0	-		
				5	80 - 100 %	8	88.89		
6	In ce masura activitatile didactice au fost desfasurate in limba specializarii urmate ?	0	0	1	0 - 20 %	0	-	0	-
				2	20 - 40 %	0	-	0	-
				3	40 - 60 %	0	-	0	-
				4	60 - 80 %	0	-	0	-
				5	80 - 100 %	0	-	0	-
				6	Nu este cazul	0	-	0	-

Explicatii :	T1 - numarul total de raspunsuri la o anumita intrebare
	N1 - numarul total de calificative de un anumit tip din cadrul T1
	T2 - valoarea T1 din care se scad raspunsurile studentilor care au avut prezenta la activitatea respectiva intre 0-20% (rsapunsurile la 13a)
	N2 - numarul total de calificative de un anumit tip din cadrul T2
	Indx(%) = (Nx/Tx)*100 - procentul calificativului fata de numarul total de raspunsuri

Observatii / Comentarii
O domnisoara foarte draguta. Cum nu am tangente foarte mari fata de materia la care preda, am apreciat foarte mult intelegerea si rabdarea de care a dat dovada. Apreciez mult politetea si respectul care ne-a fost acordat, personal am simtit pentru putinele dati de-a lungul celor 4 ani ca in fata mea vorbesc cu o persoana egala mie, si cu care pot discuta orice problema, fara teama de a fi judecat sau persecutat. Multumesc pe aceasta cale! :)

For this particular study, the experimental unit has been configured to mimic the cardiovascular system. The challenges encountered by a substance carrier device inside the cardiovascular environment with the purpose of targeted drug delivery are recreated inside the custom built platform. The setup can be divided into two main parts: the cardiovascular resemblance exhibiting characteristics similar to human blood, including the blood flow profile as well as non-Newtonian traits, and the carrier device capable of transiting and analyzing the impedance of the non-Newtonian environment. The framework is used for calibrating and validating a generalized model for sunken advancement of the robot in non-Newtonian conditions and for testing different control strategies for position control of the robot.

2.1. Non-Newtonian Cardiovascular Homology

The vascular homology is illustrated in Figure 1. The circuit is a sealed environment that houses the non-Newtonian fluid which is recirculated using a variable flow pump, SPXFLOW BL70-EB. A periodic blood flow hemodynamic profile is implemented based on the research presented in [19]. The blood flow characteristic is programmed using a real-time myRIO controller and LabVIEW programming. Two small reservoirs are used for robot insertion and extraction and also for completely sealing the circuit. The reservoirs are connected by two pipes of different diameters resembling an artery and a vein, respectively. Additionally, passing between the two venous items is realized, and the robot is capable of navigating in both directions, mimicking the transition between an artery and a vein, and vice versa.

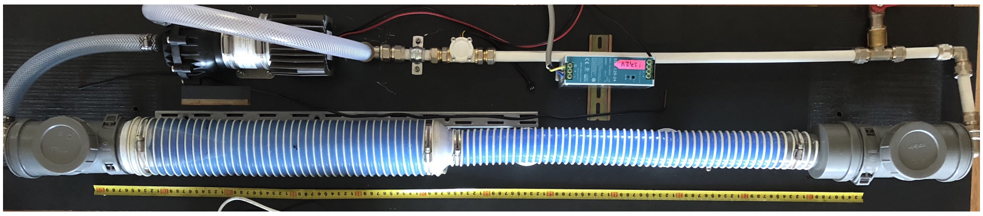


Figure 1. Experimental setup that resembles the cardiovascular system.

Fabric conditioner with similar blood characteristics has been used inside the venous system with viscosity of $\mu = 0.085 \times 10^{-5}$ kg/ms, density $\rho = 1.03/100$ kg/m^3, and pulsation frequency $\omega = 2\pi 7/6$.

During real-life blood flow scenarios, the vessels slightly expand and contract [20,21]. The experimental framework aims to also encapsulate the vessel expansion and contraction properties. Hence, the two tubes representing the vein and artery are made of polyurethane with steel insertions. During experiments, the metal insertions obtain a certain flexibility of the pipe's wall. The insertion density $\rho_{cart} = 1.14 \times 10^3$ kg/m^3 is the same for both tubes.

The properties of the larger tube are diameter $D = 160/1000$ m, wall thickness $h = 0.9/1000$ m, and a ratio between soft and hard metal insertions of $\kappa = 0.9$, while for the small tube, $D = 102/1000$ m, $h = 0.9/1000$ m, and $\kappa = 0.1$.

2.2. Autonomous Submerged Vehicle

A robot capable of transiting the cardiovascular resemblance unit has been designed, built, and programmed to achieve a single purpose: efficient targeted drug delivery at a given area in need of treatment.

The design of the submersible is inspired by autonomous underwater vehicles, reduced size submarines capable of autonomously traveling and recording underwater data [22]. The aquadynamic carcass has been 3D printed such that it has a symmetrical ellipsoidal shape with length of 0.09 m and width of 0.03 m (Figure 2).

Figure 2. Custom built autonomous submersible robot.

Inside the hull, there is a hollow for the embedded electronics that ensure proper functionality. The main brain of the robot consists of the ESP8266 module, a WiFi module and microcontroller used to manage individual modules such as: inertial measurement unit, impedance measurement unit, DC motor command unit, and WiFi communication logic (Figure 3).

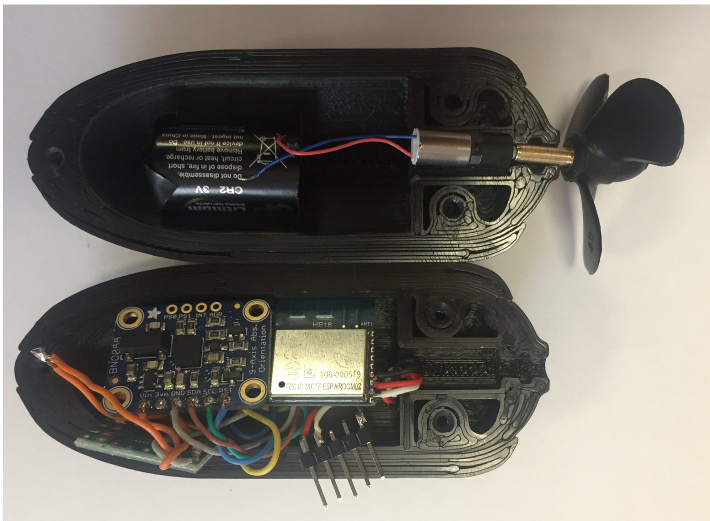


Figure 3. Incorporated electronics inside the submersible.

For the intertial measurement unit, the BNO055 9 degrees of freedom sensor has been chosen to measure the real-life acceleration of the body. The acceleration data are processed by the robot's microcontroller and transformed into velocity and position with a sampling frequency of 100 Hz. A solution of the well-studied problem of accumulating measurement errors that cause a slow drift to infinity when transforming acceleration data to position measurement is presented in [23]. The positioning algorithms are implemented inside the submersible, and the data are processed locally. This is done with the purpose of providing autonomous feedback for position control without the need of an external server. Positioning data are provided to the server only for analysis purposes. Multiple tests of different time lengths show experimentally that the algorithms presented in [23] provide accurate positioning measurements.

The submersible is equipped with a 6 mm DC motor attached to a 40 mm Graupner three-blade propeller. The DC motor is rotated by giving a voltage between 0 and 5 V through the pulse width modulation (PWM) technique.

The WiFi module is used for communication with an external server used for logging and analyzing data. A secure communication through the TCP/IP protocol is used to send the computed position and impedance information of the environment. The robot can operate in manual, automatic or emergency modes. For the manual operating mode, the