

Föreläsning 12 (Sista)

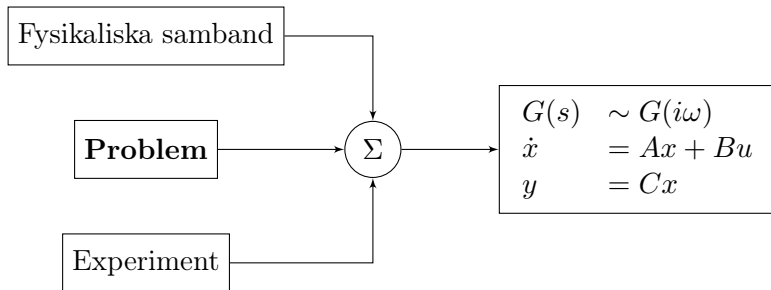
Reglerteknik AK

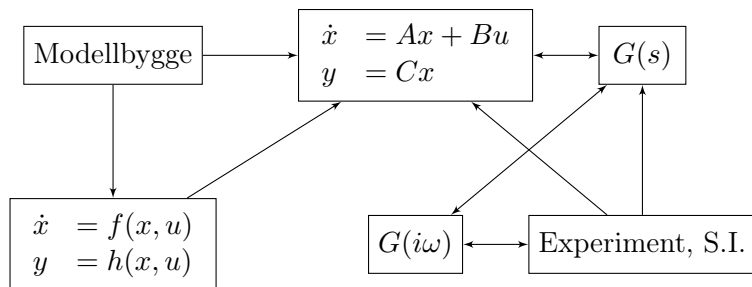
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Avdelningen för reglerteknik
Skolan för elektro- och systemteknik

10 Oktober 2013



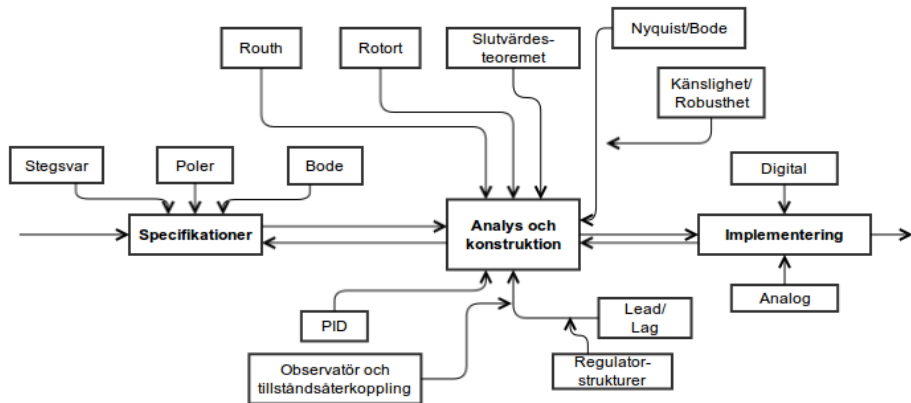




Verkliga system är komplicerade:

$$G^0(s) = G(s)[1 + \Delta_G(s)], \quad |\Delta_G(i\omega)| \leq g(\omega) \quad \forall \omega$$

Sammanfattning



Rotort:

- I. Startpunkter ($k = 0$)
- II. Ändpunkter ($k = \infty$)
- III. Var ligger ∞ ? (Asymptoter)
Riktning: $\frac{\pi}{n-m} + k \cdot \frac{2\pi}{n-m}$
Skärningspunkt: $\frac{1}{n-m} (\sum p_i - \sum q_j)$
- IV. Skärning med reella axeln. ”*Udda summa*”
- V. Skärning med imaginära axeln. Ansätt $s = i\omega$
- VI. Rita rotort och **dra slutsats**

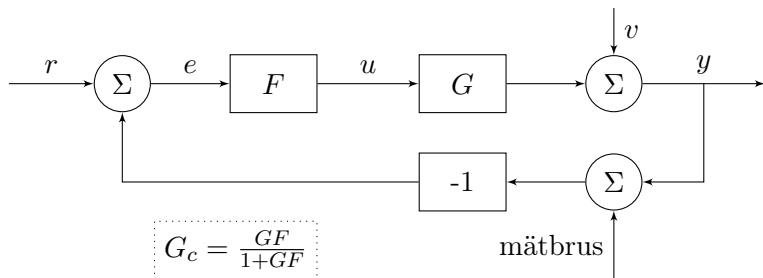
Slutvärdesteoremet:

Kom ihåg att kolla att slutvärdet existerar! (\approx stabilitet)

Steg $\frac{1}{s}$

Ramp $\frac{1}{s^2}$

Sammanfattning - Specifikationer



Tidsdomänen:

Stigtid: T_r

Insvängningstid: T_s

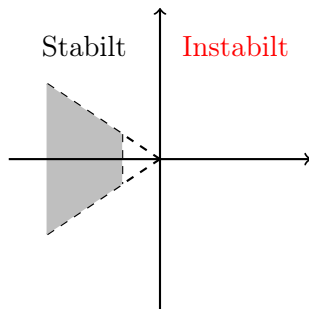
Översläng: M

Frekvensdomänen:

Bandbredd: ω_B

Resonanstopp: M_p

Resonansfrekvens: ω_r



Avstånd till origo \approx snabbhet

Vinkel \approx svängighet

Nyquist:

$$G(i\omega)$$

Bode:

$$|G(i\omega)|, \arg [G(i\omega)]$$

Tolkning \leftrightarrow rita

$$\left. \begin{array}{l} \text{skärfrekvens: } \omega_c \\ \text{fasmarginall: } \varphi_m \end{array} \right\} \iff |G(i\omega_c)| = 1$$

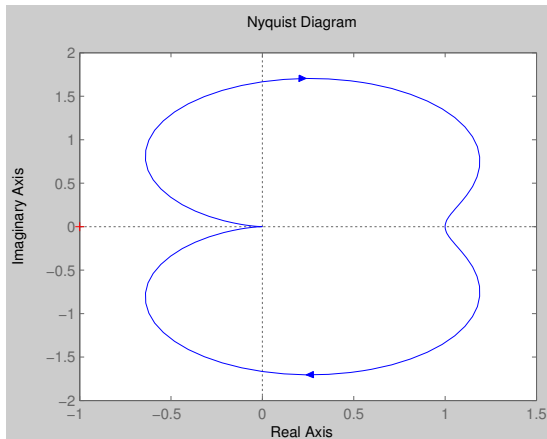
Amplitudmarginalen kan läsas av i Bodediagram eller Nyquistkurva (se figur 5.2 samt 5.3 i boken).

Sammanfattning - Nyquistkriteriet

Antag att $G_o(s)$ saknar poler i H.H.P. och att Nyquistkurvan $\mathbf{e}j$ omcirklar -1 .

$\Rightarrow G_c(s)$ saknar poler i H.H.P.

\Rightarrow Stabilt återkopplat system.



Öppna systemets Bodediagram \leftrightarrow Slutna systemets Bodediagram

Fördubbla $\omega_c \leftrightarrow$ Fördubbla ω_B

$\varphi_m \sim M_p$

liten \rightarrow stor ($\approx 50^\circ - 60^\circ$ OK)

$G_o(i\omega)$ stor $\Rightarrow G_c(i\omega) \approx 1$

$G_o(i\omega) \approx -1 \Rightarrow G_c(i\omega)$ stor

Känslighet (störningar):

$$S = \frac{1}{1 + FG}$$

Robusthet (modellfel):

$$T = \frac{FG}{1 + FG} = 1 - S$$

PID-regulator:

$$U(s) = K \left(1 + \frac{1}{T_I} \frac{1}{s} + T_D s \right) = K_P + K_I \frac{1}{s} + K_D s$$

Lead-/Lag-länk:

$$F(s) = K \frac{\tau_D s + 1}{\beta \tau_D s + 1} \frac{\tau_I s + 1}{\tau_I s + \gamma}$$

Önska $\bar{\omega}_c$ (Lägg till 5.7° extra på fasmarginalen, φ_m) $\implies \beta$.

$$\tau_I = \frac{10}{\bar{\omega}_c} \text{ (iterera)}$$

Välj γ liten.

$$\begin{cases} \dot{x} &= Ax + Bu \\ y &= Cx \end{cases}$$

$$\begin{aligned} \dot{\hat{x}} &= A\hat{x} + Bu + K(y - C\hat{x}) \\ \det [sI - (A - KC)] &= 0 \end{aligned}$$

$$\begin{aligned} u &= -Lx + l_0r \\ \det [sI - (A - BL)] &= 0 \end{aligned}$$

⇓

$$u = -L\hat{x} + l_0r$$

Styrbarhet + Observerbarhet

Regulatorstrukturer:

- Framkoppling
- Kaskadreglering
- Otto Smith

Implementering:

- Euler bakåt
- Tustins formuel

Differentialekvationer \mapsto differensekvationer

- Man får ha boken och Beta med sig (samt. miniräknare). Läs boken innan tentan!
- Problemlösning (ej utantillavskrivningar). Träna på gamla tentor!
- **Observera** att man måste vara anmäld för att få skriva tentan!


Master's programme in Systems, Control and Robotics!







- Olinjär reglering, period 2
- Hybrida och inbyggda reglersystem, period 3
- Reglerteknik, fortsättningskurs , period 4
- Modellering av dynamiska system, period 1

According to McKinsey Global Institute (Maj 2103):

Disruptive technologies: Advances that will transform life, business, and the global economy

Speed, scope, and economic value at stake of 12 potentially economically disruptive technologies

	Illustrative rates of technology improvement and diffusion	Illustrative groups, products, and resources that could be impacted ¹	Illustrative pools of economic value that could be impacted ¹
	Mobile Internet \$5 million vs. \$400² Price of the fastest supercomputer in 1975 vs. that of an iPhone 4 today, equal in performance (MFLOPS) 5x Growth in sales of smartphones and tablets since launch of iPhone in 2007	4.3 billion People remaining to be connected to the Internet, potentially through mobile Internet 1 billion Transaction and interaction workers, nearly 40% of global workforce	\$1.7 trillion GDP related to the Internet \$25 trillion Interaction and transaction worker employment costs, 70% of global employment costs
	Automation of knowledge work 100x Increase in computing power from IBM's Deep Blue (chess champion in 1997) to Watson (Jeopardy winner in 2011) 400+ million Increase in number of users of intelligent digital assistants like Siri and Google Now in past 3 years	230+ million Knowledge workers, 9% of global workforce 1.1 billion Smartphone users, with potential to use automated digital assistance apps	\$9+ trillion Knowledge worker employment costs, 27% of global employment costs
	The Internet of Things 300% Increase in connected machine-to-machine devices over past 5 years 80-90% Price decline in MEMS (microelectromechanical systems) sensors in past 5 years	1 trillion Things that could be connected to the Internet across industries such as manufacturing, health care, and mining 100 million Global machine to machine (M2M) device connections across sectors like transportation, security, health care, and utilities	\$36 trillion Operating costs of key affected industries (manufacturing, health care, and mining)
	Cloud technology 18 months Time to double server performance per dollar 3x Monthly cost of owning a server vs. renting in the cloud	2 billion Global users of cloud-based email services like Gmail, Yahoo, and Hotmail 80% North American institutions hosting or planning to host critical applications on the cloud	\$1.7 trillion GDP related to the Internet \$3 trillion Enterprise IT spend
	Advanced robotics 75-85% Lower price for Baxter ³ than a typical industrial robot 170% Growth in sales of industrial robots, 2009-11	320 million Manufacturing workers, 12% of global workforce 250 million Annual major surgeries	\$6 trillion Manufacturing worker employment costs, 19% of global employment costs \$2-3 trillion Cost of major surgeries
	Autonomous and near-autonomous vehicles 7 Miles driven by top-performing driverless car in 2004 DARPA Grand Challenge along a 150-mile route 1,540 Miles cumulatively driven by cars competing in 2005 Grand Challenge 300,000+ Miles driven by Google's autonomous cars with only 1 accident (which was human-caused)	1 billion Cars and trucks globally 450,000 Civilian, military, and general aviation aircraft in the world	\$4 trillion Automobile industry revenue \$155 billion Revenue from sales of civilian, military, and general aviation aircraft

	Next-generation genomics	10 months Time to double sequencing speed per dollar 100x Increase in acreage of genetically modified crops, 1995–2012	26 million Annual deaths from cancer, cardiovascular disease, or type 2 diabetes 2.6 billion People employed in agriculture	\$6.5 trillion Global health-care costs \$1.1 trillion Global value of wheat, rice, maize, soy, and barley
	Energy storage	40% Price decline for a lithium-ion battery pack in an electric vehicle since 2009	1 billion Cars and trucks globally 1.2 billion People without access to electricity	\$2.5 trillion Revenue from global consumption of gasoline and diesel \$100 billion Estimated value of electricity for households currently without access
	3D printing	90% Lower price for a home 3D printer vs. 4 years ago 4x Increase in additive manufacturing revenue in past 10 years	320 million Manufacturing workers, 12% of global workforce 8 billion Annual number of toys manufactured globally	\$11 trillion Global manufacturing GDP \$85 billion Revenue from global toy sales
	Advanced materials	\$1,000 vs. \$50 Difference in price of 1 gram of nanotubes over 10 years 116x Strength-to-weight ratio of carbon nanotubes vs. steel	7.6 million tons Annual global silicon consumption 45,000 metric tons Annual global carbon fiber consumption	\$1.2 trillion Revenue from global semiconductor sales \$4 billion Revenue from global carbon fiber sales
	Advanced oil and gas exploration and recovery	3x Increase in efficiency of US gas wells, 2007–11 2x Increase in efficiency of US oil wells, 2007–11	22 billion Barrels of oil equivalent in natural gas produced globally 30 billion Barrels of crude oil produced globally	\$90 billion Revenue from global sales of natural gas \$3.4 trillion Revenue from global sales of crude oil
	Renewable energy	85% Lower price for a solar photovoltaic cell per watt since 2000 19x Growth in solar photovoltaic and wind generation capacity since 2000	21,000 TWh Annual global electricity consumption 13 billion tons Annual CO ₂ emissions from electricity generation, more than from all cars, trucks, and planes	\$3.5 trillion Value of global electricity consumption \$80 billion Value of global carbon market transactions

1 Not comprehensive; indicative groups, products, and resources only.

2 For CDC-7600, considered the world's fastest computer from 1969 to 1975; equivalent to \$32 million in 2013 at an average inflation rate of 4.3% per year since launch in 1969.

3 Baxter is a general-purpose basic manufacturing robot developed by startup Rethink Robotics.

SOURCE: McKinsey Global Institute analysis