Dinamik Sistemler ve Kontrole Giriş

T.C. Trakya Üniversitesi
Mühendislik Fakültesi
Elektrik - Elektronik Mühendisliği Bölümü
Kontrol Anabilim Dalı

Dr. Öğr. Üyesi Işık İlber Sırmatel

sirmatel.github.io/teaching/EEE126/

Konu listesi

1. Giriş ve tanımlar
2. Teori
3. Dinamik sistemlere örnekler
4. Yöntem sınıfları
5. Uygulamalar

Bölüm 1

Giriş ve tanımlar

Dinamik sistemler ve kontrol - Tanımlar

dinamik sistemler:
hareket eden sistemler

kontrol: sistemlerin istenen şekilde davranmasını sağlamak

otomatik kontrol: dinamik sistemlerde otonom davranış tasarımı

Kontrol uygulamalarına örnekler (1/2)

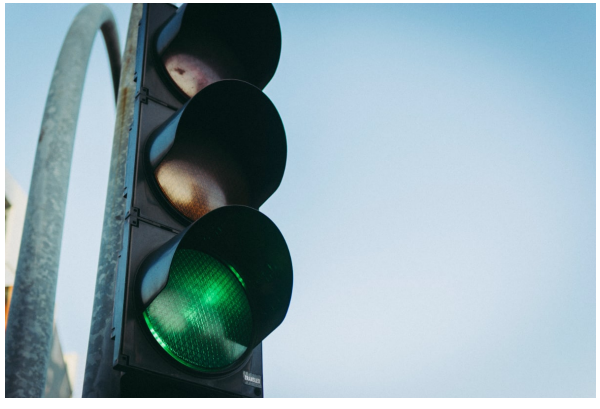
taşıtlar

elektrikli/elektronik cihazlar

altyapı ağları

robotlar

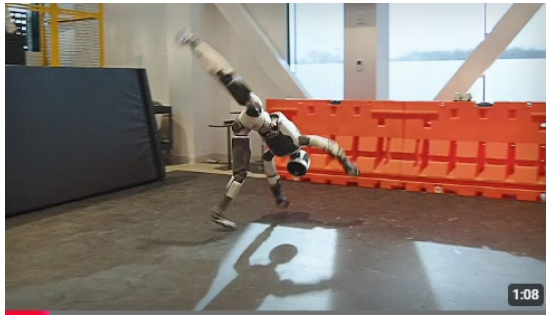
ulaşım sistemleri



kimyasal tesisler

Kontrol uygulamalarına örnekler (2/2)

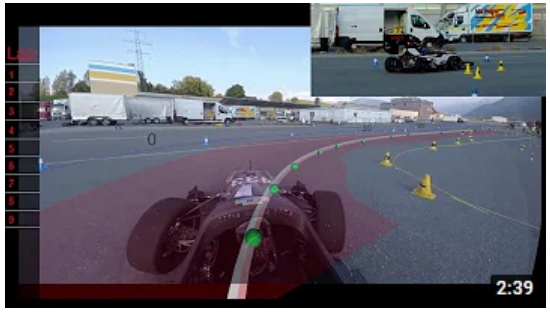
humanoid robot



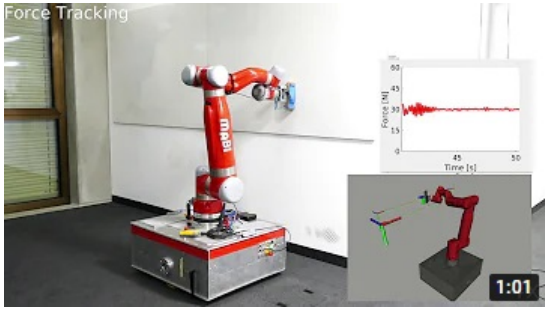
quadrotor

quadruped robot

otonom araç

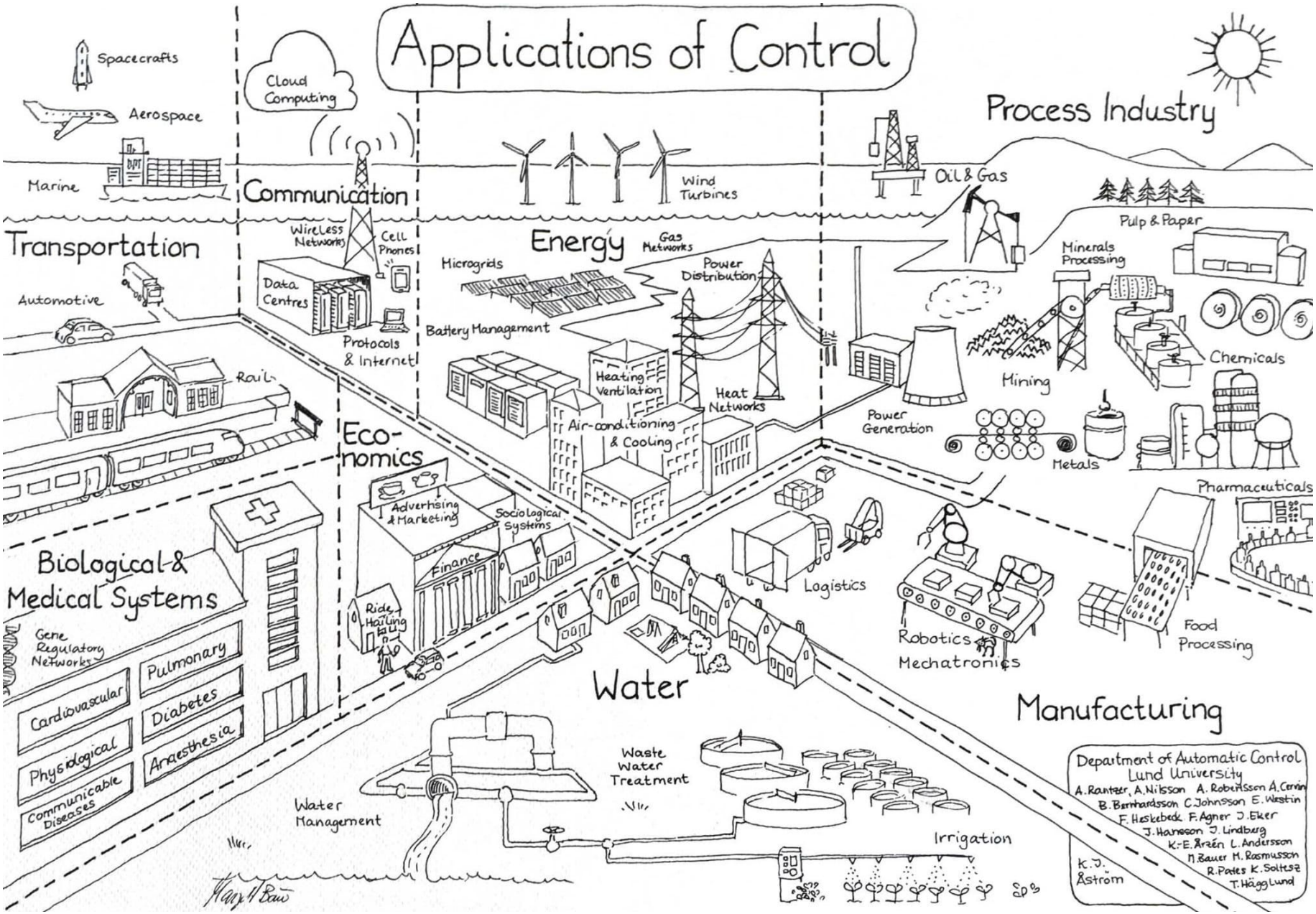


endüstriyel robot



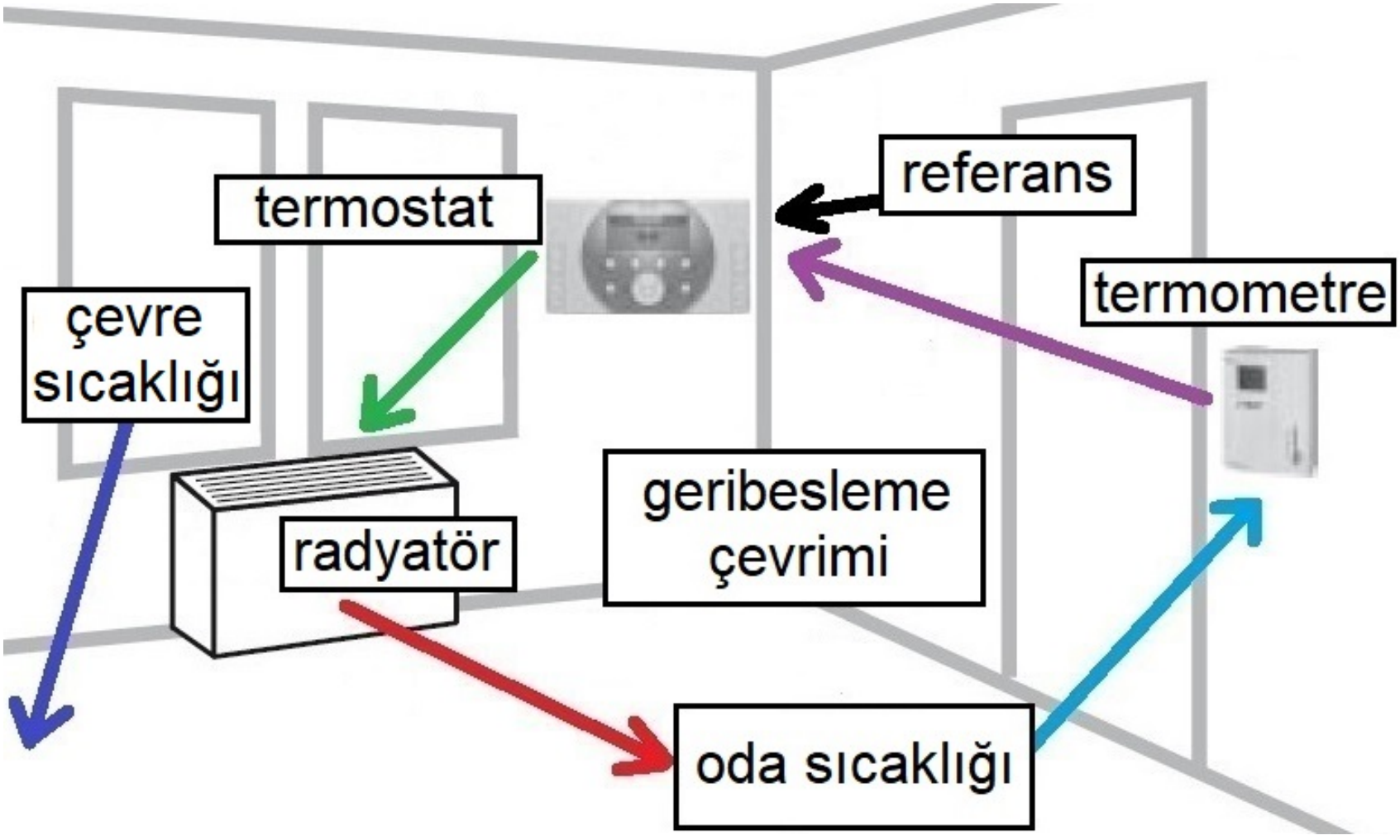
uçurtma-dinamo

Kontrol uygulama alanları

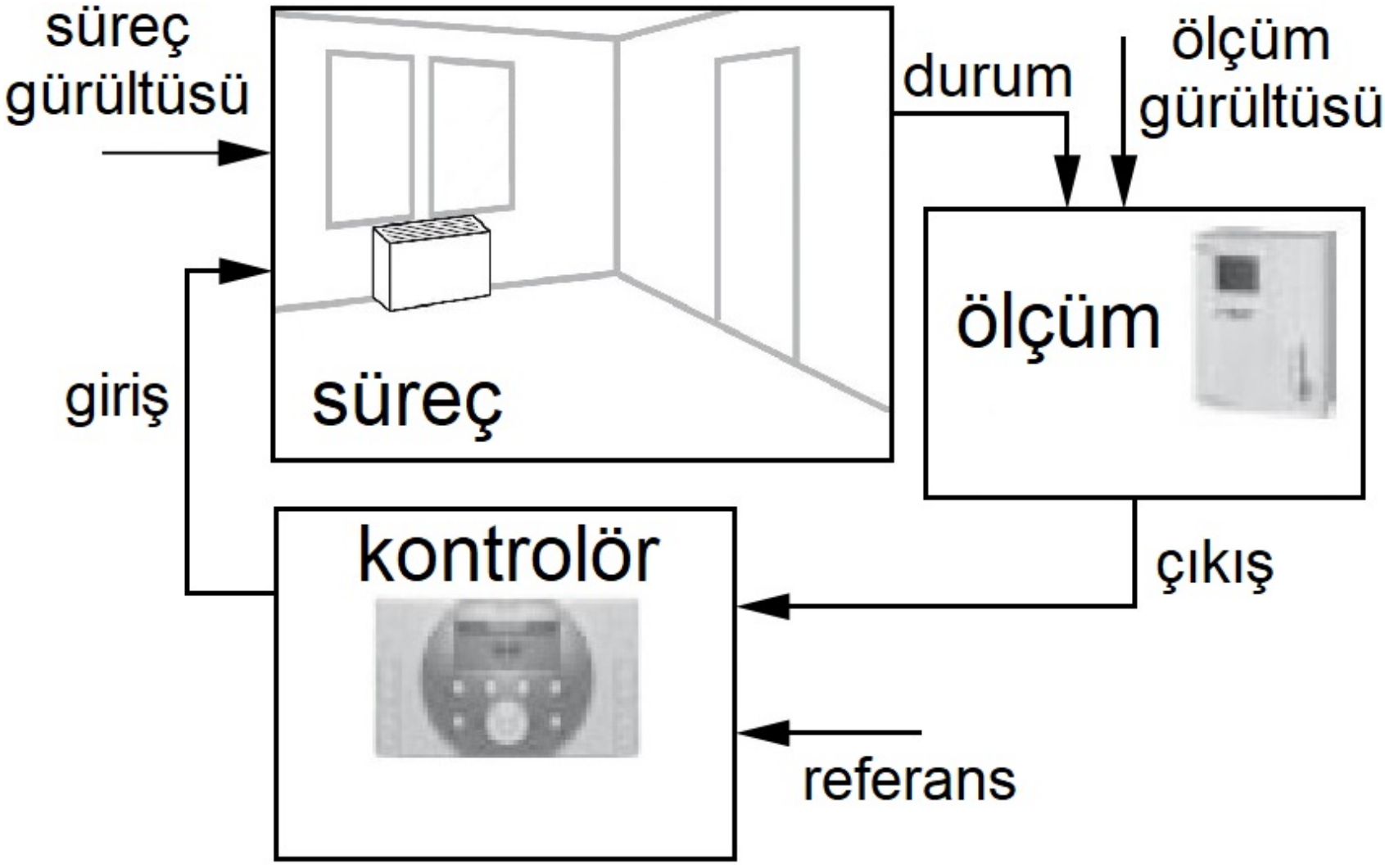


Kaynak: Otomatik Kontrol Bölümü, Lund Üniversitesi, İsveç

Kontrol - Örnek: Oda sıcaklığı



Kontrol sistemlerinin yapısı



Bölüm 2

Teori

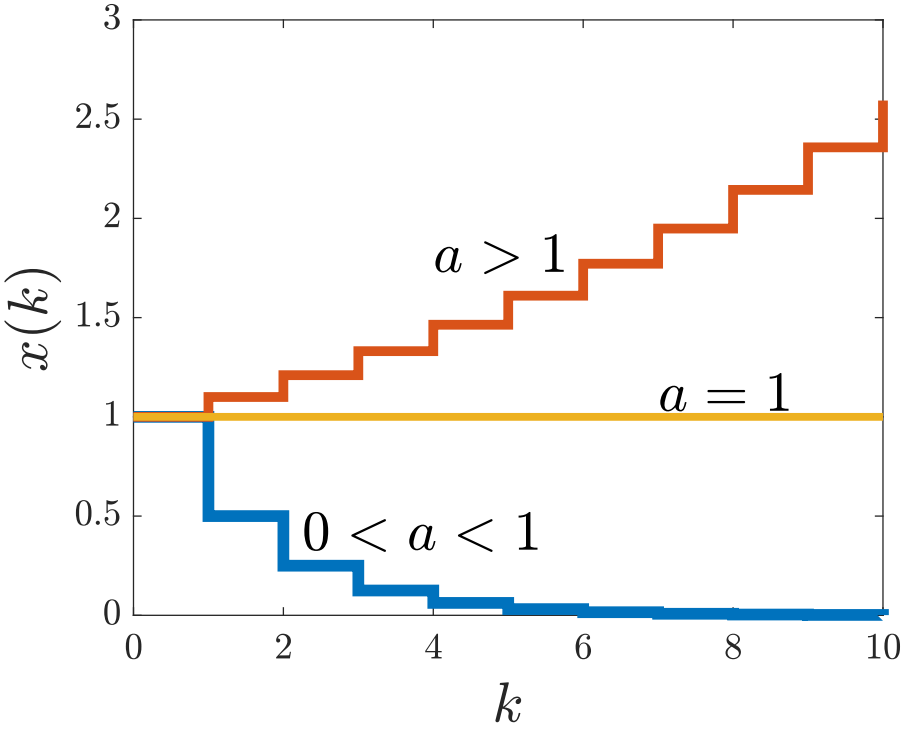
Bir boyutlu fark denklemi

$$x(k+1) = ax(k) \qquad x(0) = x_0$$

$$x \in \mathbb{R} \qquad k \in \mathbb{Z} \qquad a \in \mathbb{R} \qquad x_0 \in \mathbb{R}$$

benzetim:

$$x(1) = ax(0)$$
$$x(2) = ax(1)$$
$$x(3) = ax(2)$$
$$\vdots$$



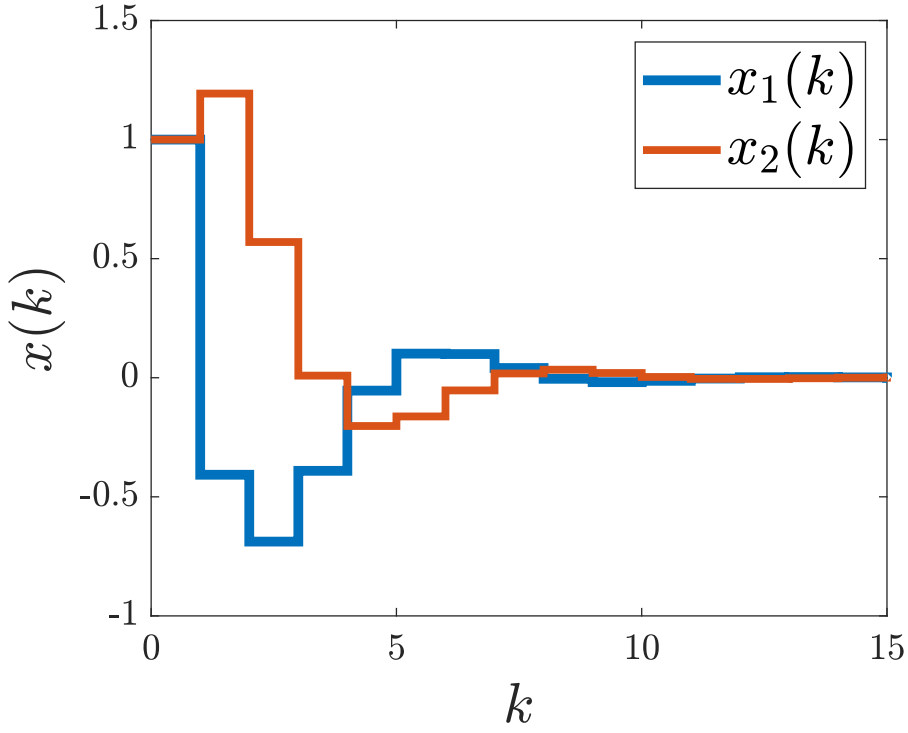
İki boyutlu fark denklemi

$$x(k+1) = Ax(k) \qquad x(0) = x_0$$

$$x \in \mathbb{R}^n \qquad k \in \mathbb{Z} \qquad A \in \mathbb{R}^{n \times n} \qquad x_0 \in \mathbb{R}^n$$

benzetim:

$$x(1) = Ax(0)$$
$$x(2) = Ax(1)$$
$$x(3) = Ax(2)$$
$$\vdots$$



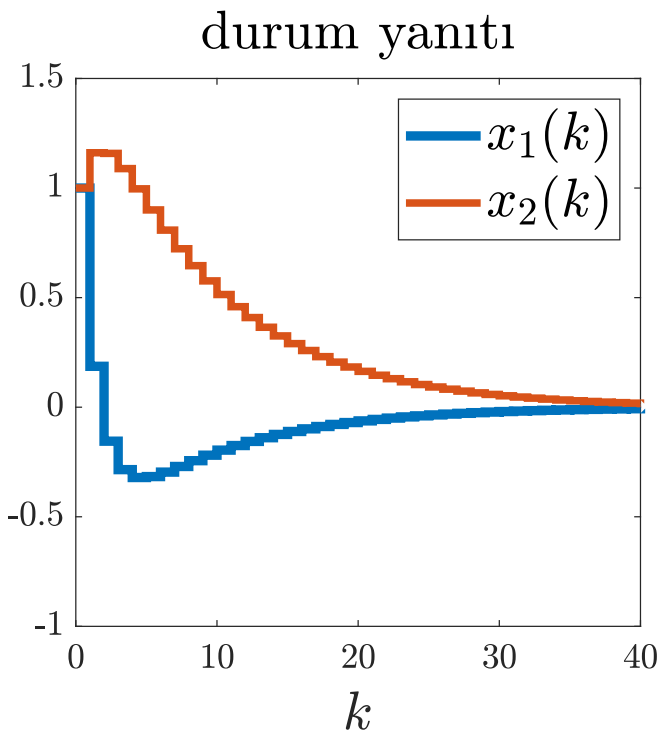
$$A = \begin{bmatrix} 0.12 & -0.53 \\ 0.53 & 0.66 \end{bmatrix}$$

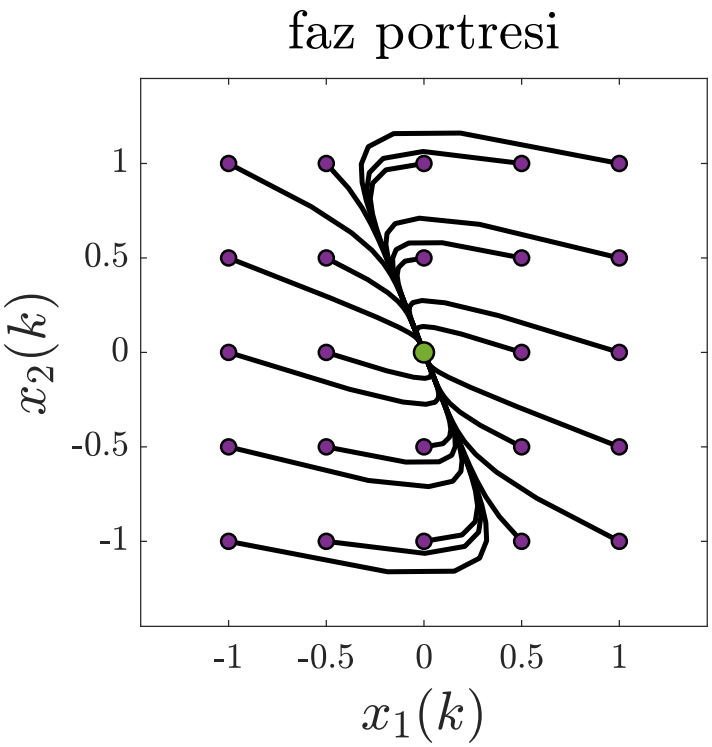
Özdeğerler, durum yanıtı, kararlılık

örnek 1: $x(k+1) = Ax(k)$ $A = \begin{bmatrix} 0.38 & -0.19 \\ 0.19 & 0.96 \end{bmatrix}$

özdeğerler: $\lambda_1 = 0.4559 \quad \lambda_2 = 0.8917$

$|\lambda_i| < 1 \ (i = \{1, 2\}) \Rightarrow$ asimptotik kararlı



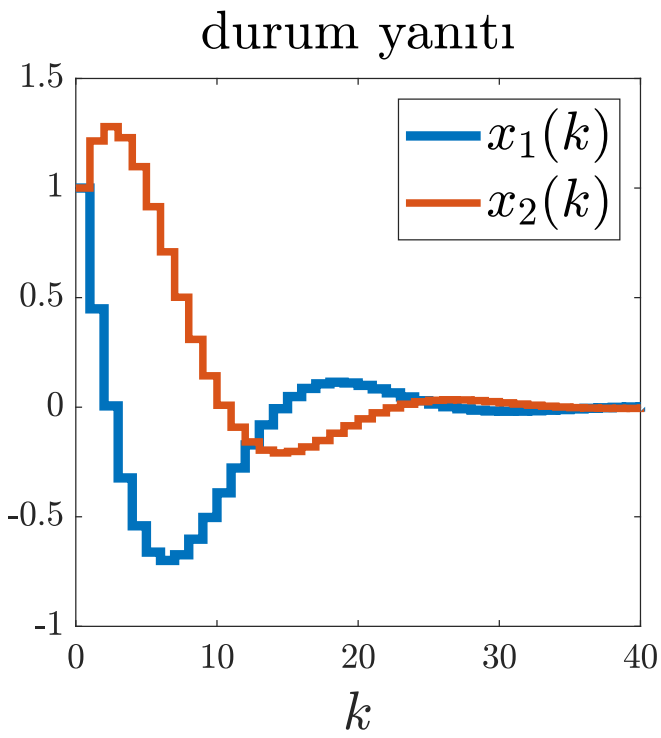


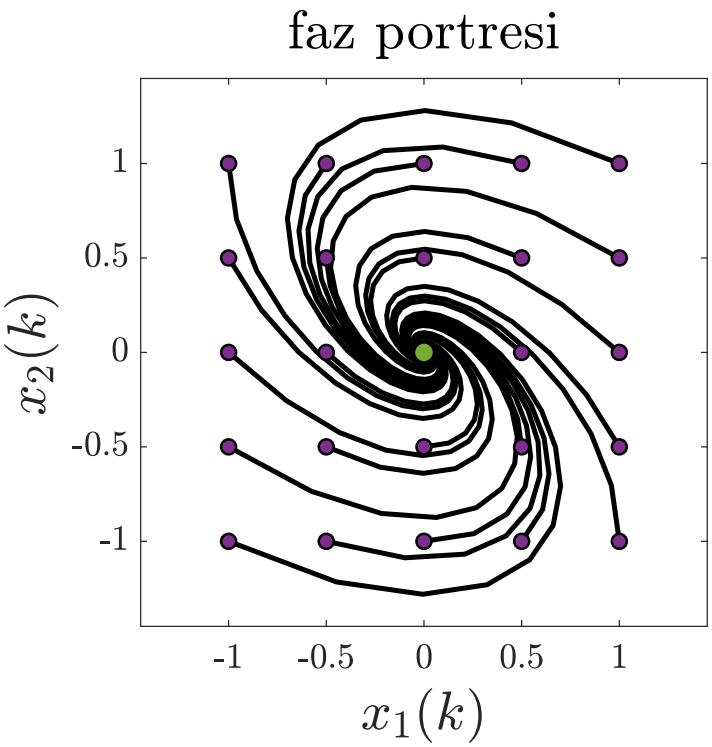
Özdeğerler, durum yanıtı, kararlılık

örnek 2: $x(k+1) = Ax(k)$ $A = \begin{bmatrix} 0.70 & -0.25 \\ 0.25 & 0.95 \end{bmatrix}$

özdeğerler: $\lambda_1 = 0.83 + 0.22j$ $\lambda_2 = 0.83 - 0.22j$

$|\lambda_i| < 1 \ (i = \{1, 2\}) \Rightarrow$ asimptotik kararlı



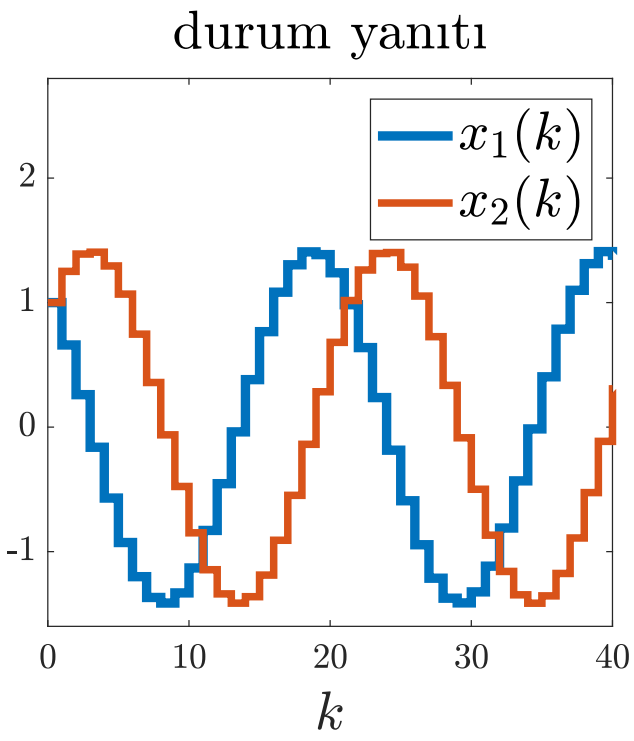


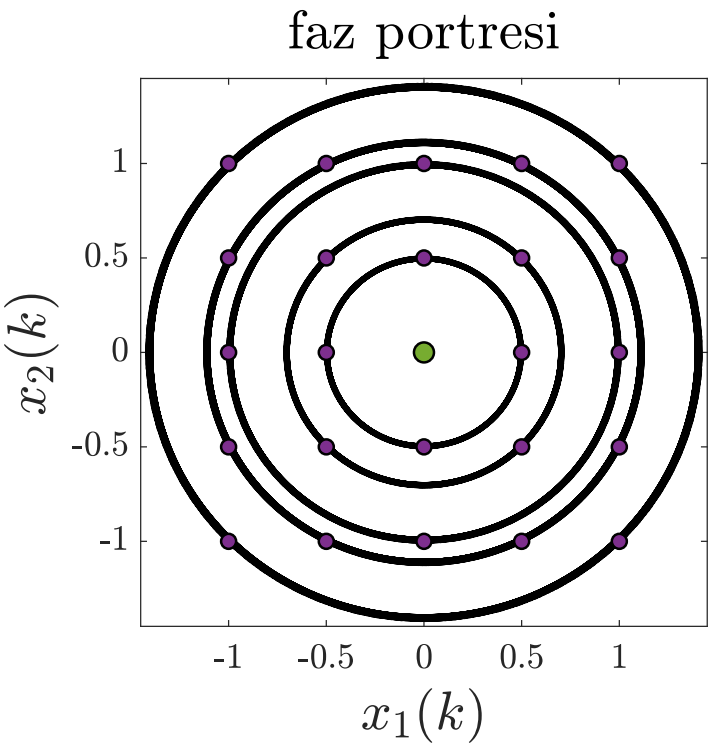
Özdeğerler, durum yanıtı, kararlılık

örnek 3: $x(k+1) = Ax(k) \qquad A = \begin{bmatrix} 0.95 & -0.29 \\ 0.29 & 0.95 \end{bmatrix}$

özdeğerler: $\lambda_1 = 0.95 + 0.29j \quad \lambda_2 = 0.95 - 0.29j$

$|\lambda_i| = 1 \ (i = \{1, 2\}) \Rightarrow$ (marjinal) kararlı



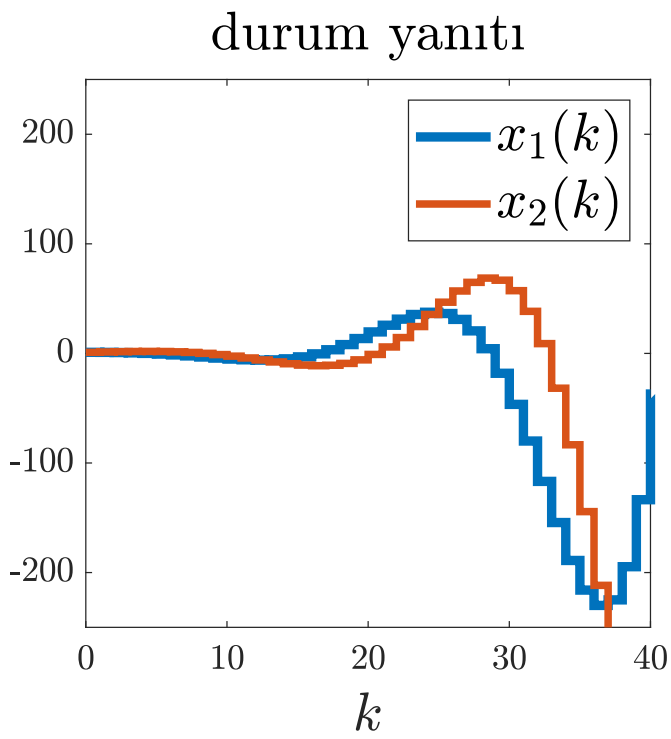


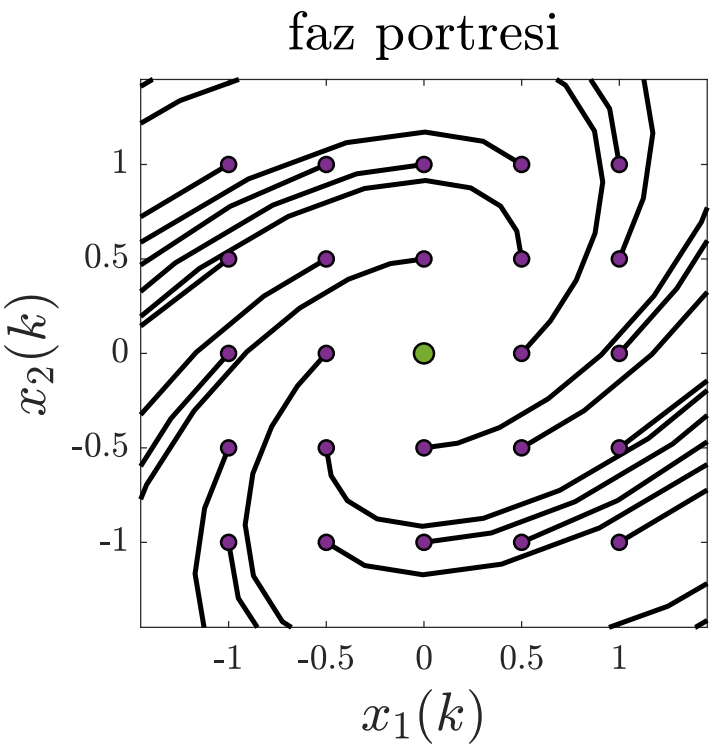
Özdeğerler, durum yanıtı, kararlılık

örnek 4: $x(k+1) = Ax(k) \qquad A = \begin{bmatrix} 1.29 & -0.34 \\ 0.34 & 0.95 \end{bmatrix}$

özdeğerler: $\lambda_1 = 1.12 + 0.29j \quad \lambda_2 = 1.12 - 0.29j$

$$|\lambda_i| > 1 \ (i = \{1, 2\}) \Rightarrow \text{kararsız}$$

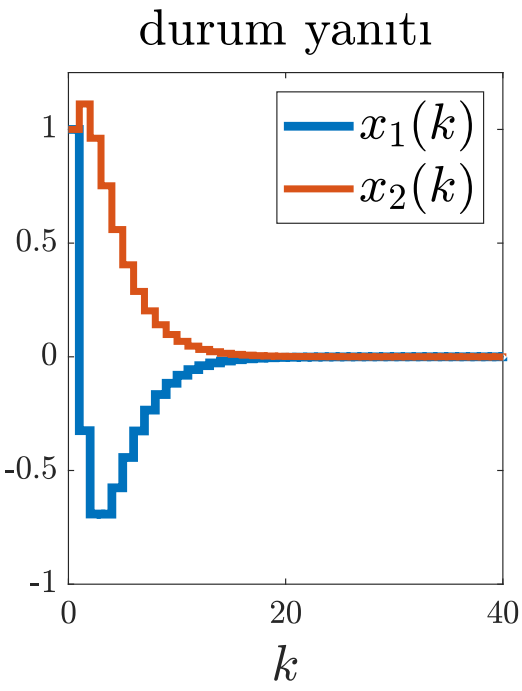


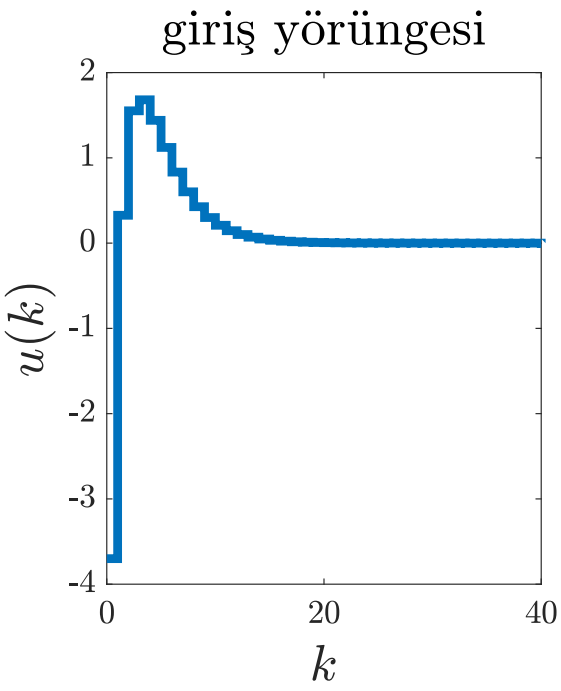


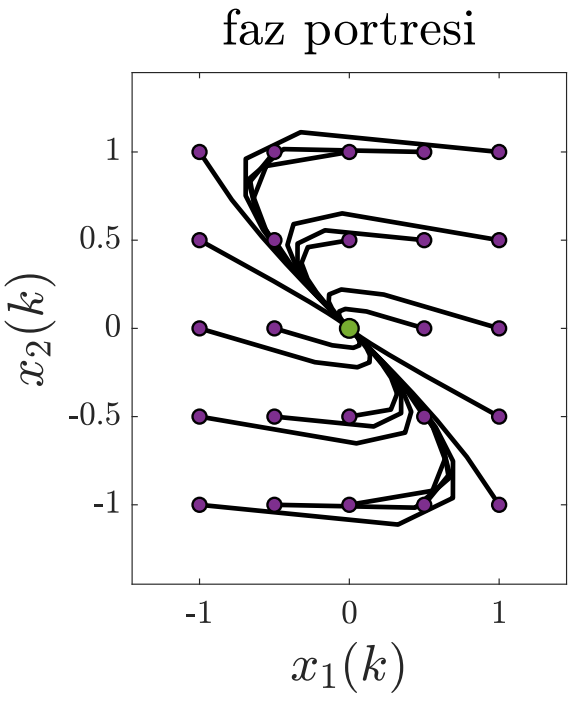
Kontrol ile kararlılaştırma

örnek 5: $x(k+1) = Ax(k) + Bu(k), \qquad u(k) = -Kx(k)$

$$A = \begin{bmatrix} 1.29 & -0.34 \\ 0.34 & 0.95 \end{bmatrix} \qquad B = \begin{bmatrix} 0.34 \\ 0.05 \end{bmatrix} \qquad K = \begin{bmatrix} 3.1 & 0.61 \end{bmatrix}$$







Bölüm 3

Dinamik sistemlere örnekler

Çeşitli disiplinlerden örnekler

Figure 3.13: Schematic diagrams for different disciplines

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Mekanik denge sistemleri

Figure 3.6: Balance systems

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Araç hareketi için bisiklet modeli

Figure 3.17: Vehicle steering dynamics

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Avcı-av sistemleri

Figure 3.7: Predator versus prey

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Hava taşıtlarında vektörlü itki

Figure 3.18: Vectored thrust aircraft

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İnternette çok aşamalı ağ sistemi

Figure 1.8: A multitier system for services on the Internet

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Termoakışkan sistemleri

Figure 3.19: Two thermofluid systems

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Tedarik zinciri

Figure 1.9: Supply chain dynamics

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Biyolojik devreler

Figure 3.25: Biological circuitry

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Karayolu trafiği

Figure 3.9: A simple model for a traffic light

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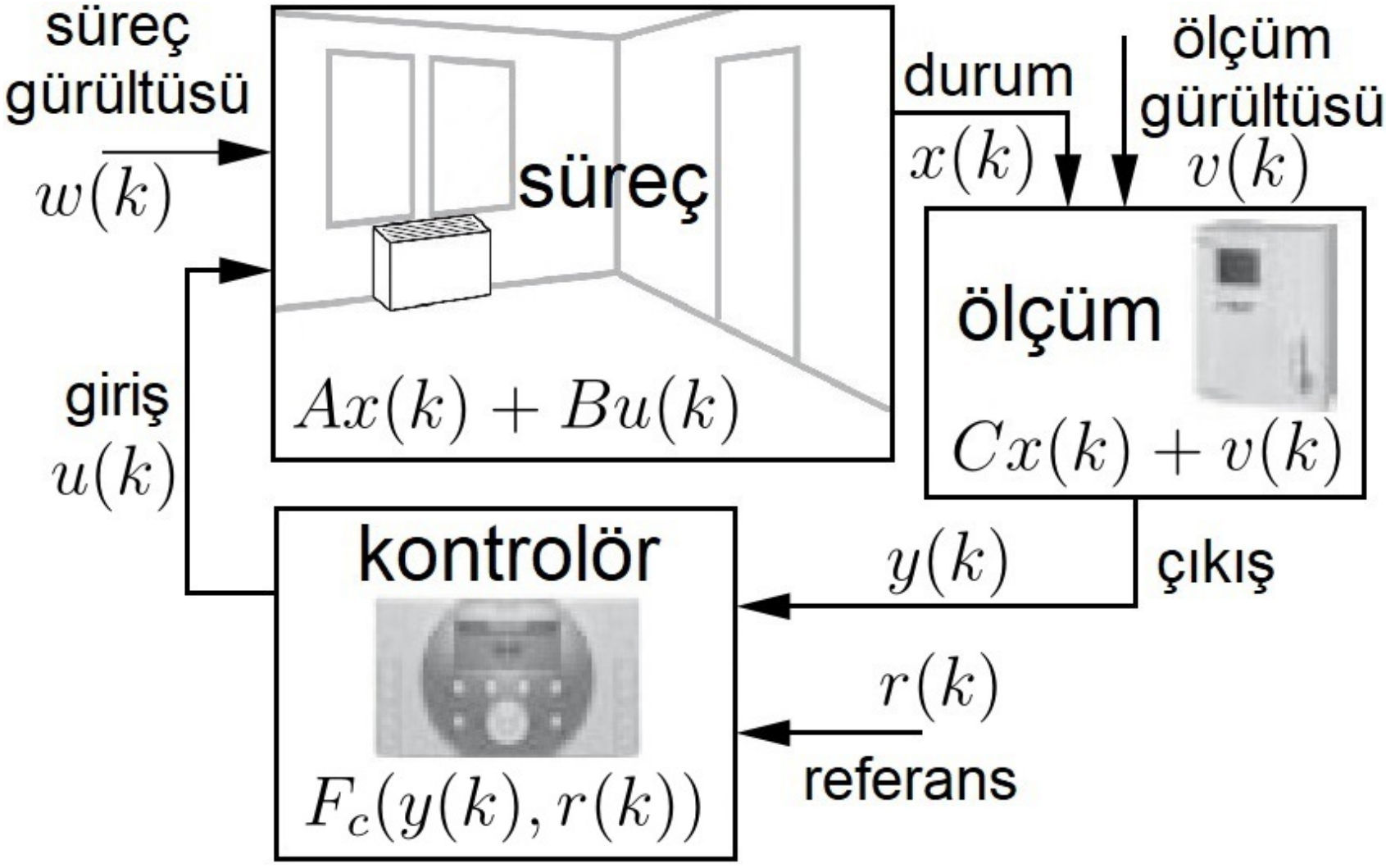
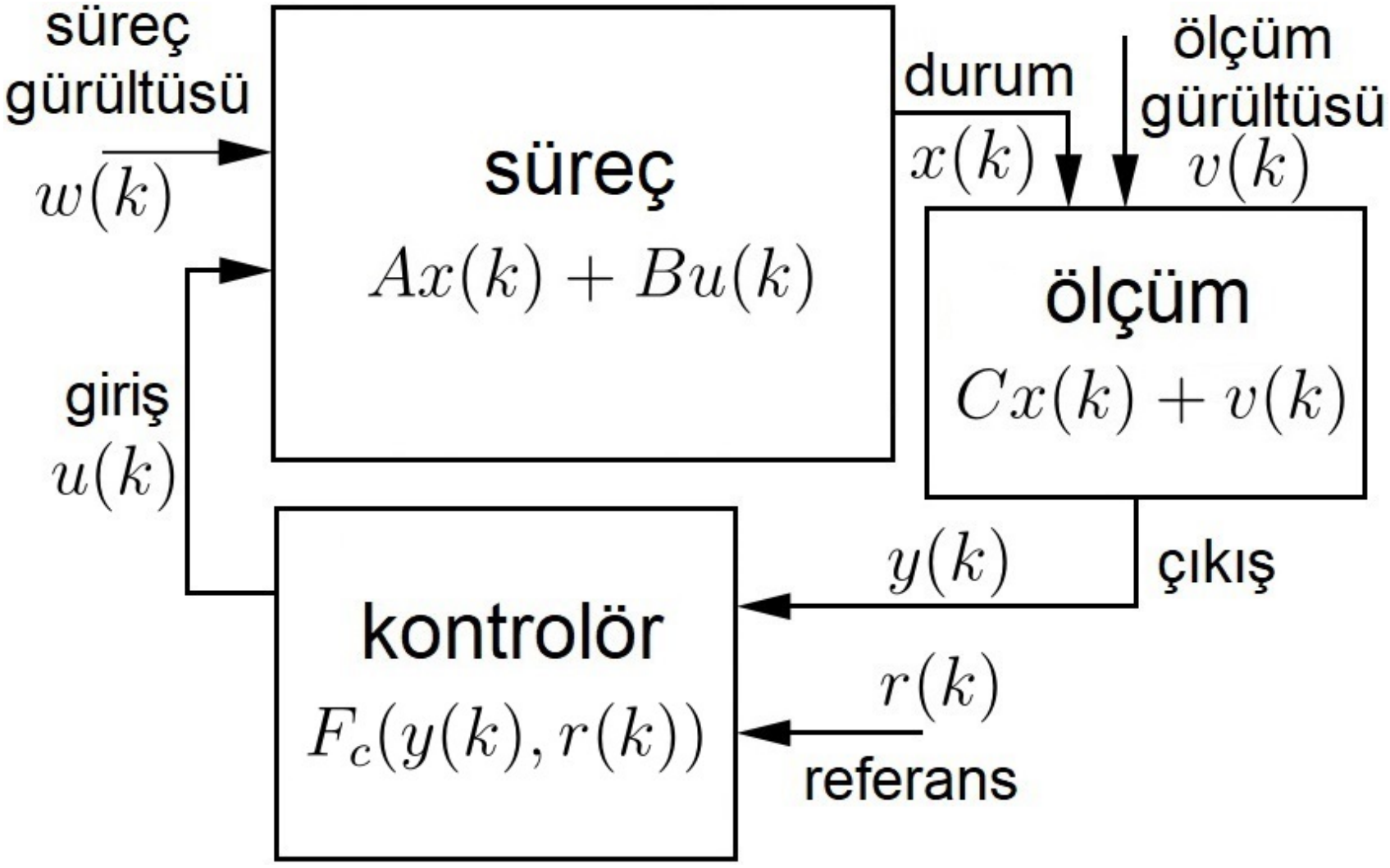
Bölüm 4

Yöntem sınıfları

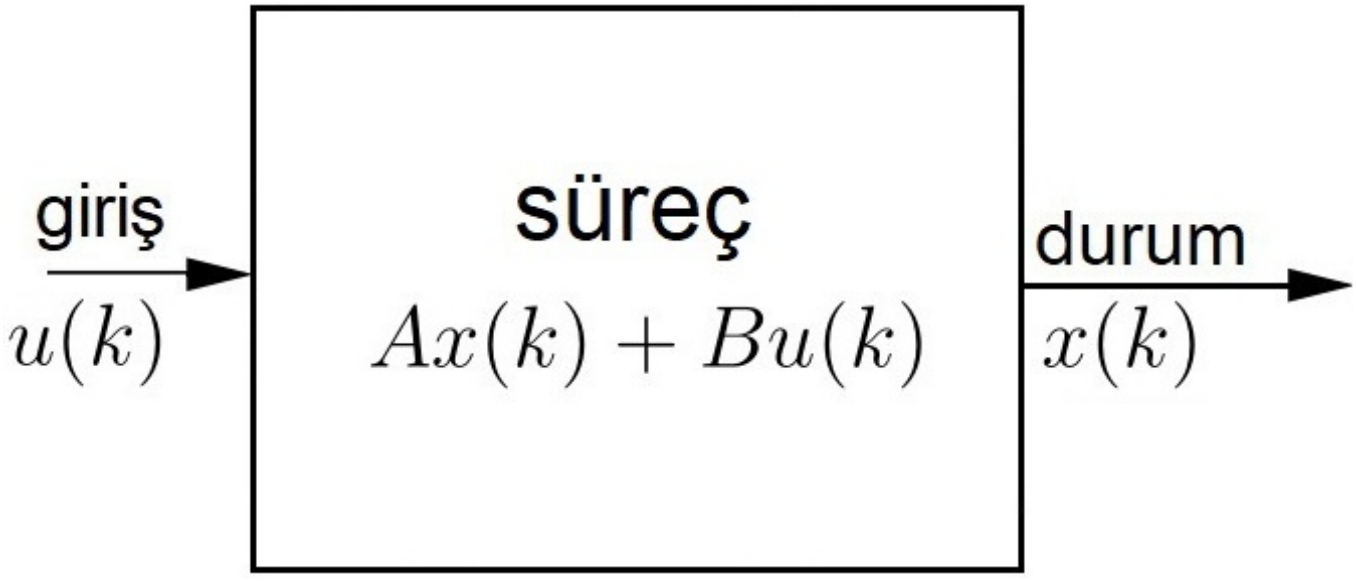
Kontrol sistemi (oda sıcaklığı)



Kontrol sistemi (genel)



Dinamik benzetim (*simulation*)

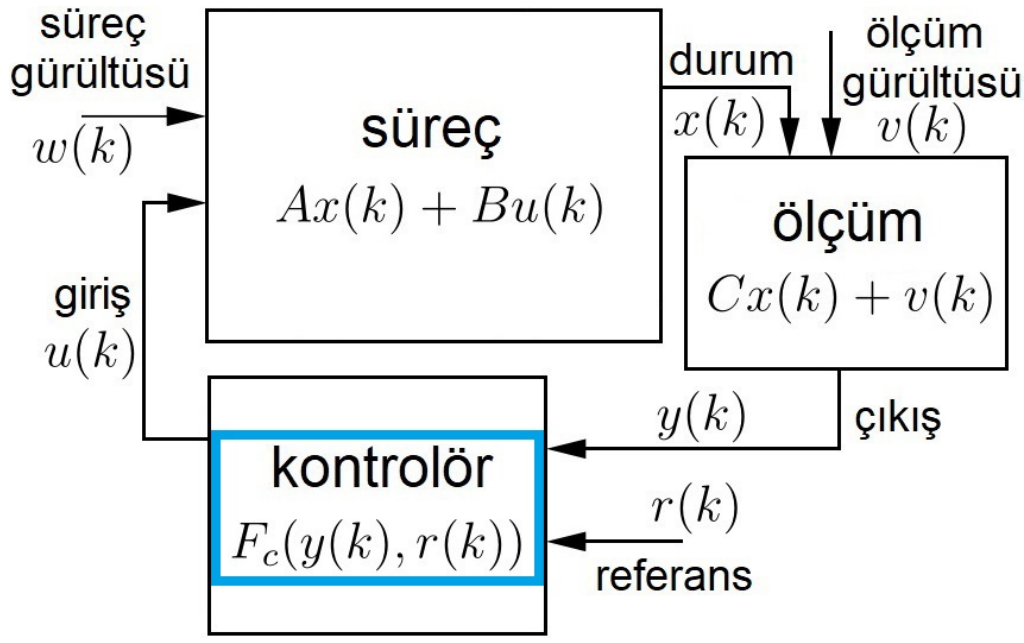


verilenler: dinamik model (A, B), başlangıç koşulu $x(0)$, giriş yörüngesi $(u(0), \ldots, u(K-1))$

problem: durum yörüngesini $(x(1), \ldots, x(K))$ hesaplamak

bağlantılar: Dynamical system, Dynamical system simulation

Geribeslemeli kontrol (*feedback control*)

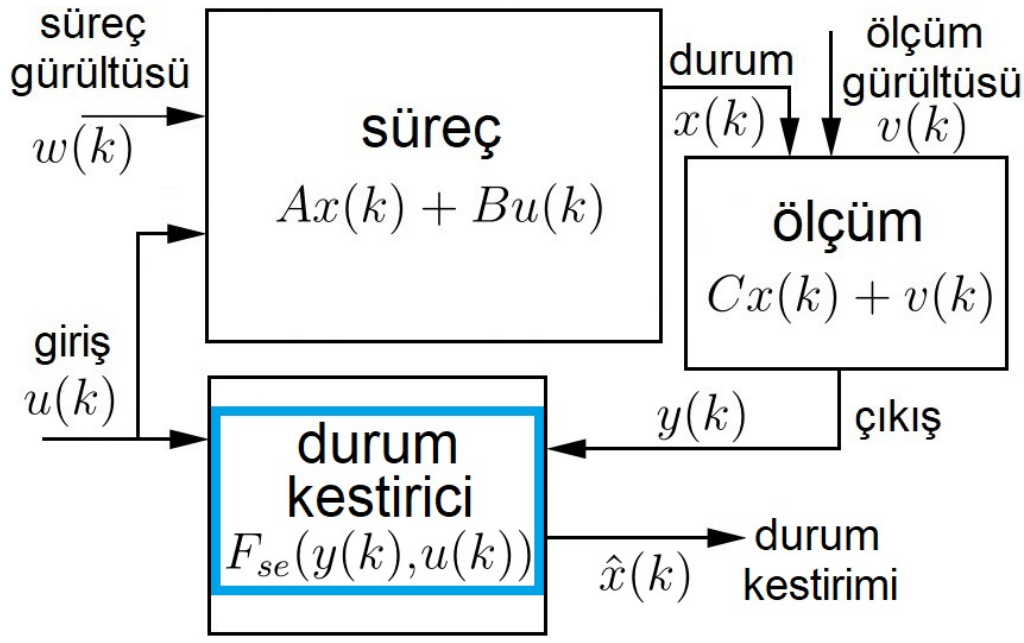


verilenler: dinamik model (A, B), **tasarım belirtimleri** (*design specifications*) (kararlılık, başarım, dayanıklılık vb.)

problem: kontrolörü ($F_c(\cdot)$ fonksiyonunu) tasarlamak

bağlantılar: Control system, Closed-loop controller, PID controller, Model predictive control, Control theory

Durum kestirme (*state estimation*)

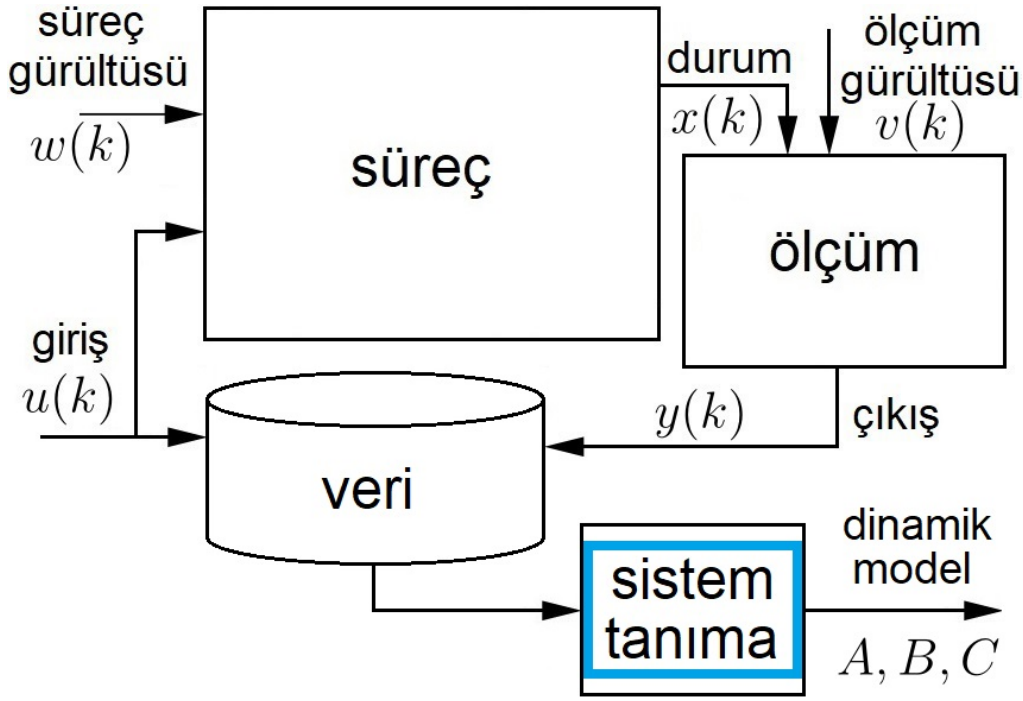


verilenler: dinamik model (A, B, C), gürültülerin ($w(k)$, $v(k)$) istatistikleri

problem: durum kestiriciyi ($F_{se}(\cdot)$ fonksiyonunu) tasarlamak

bağlantılar: State observer, Kalman filter, Extended Kalman filter, Moving horizon estimation, Estimation theory

Sistem tanıma (*system identification*)



verilenler: ölçüm yörüngesi $(y(0), \ldots, y(K))$, giriş yörüngesi $(u(0), \ldots, u(K))$, gürültülerin $(w(k),\ v(k))$ istatistikleri

problem: dinamik modeli ve/veya parametrelerini hesaplamak

bağlantılar: System identification, Nonlinear system identification, Grey box model, Estimation theory

Diğer bazı yöntem sınıfları

- yörünge planlama (*trajectory planning*): dinamik model biliniyor. problem: istenen koşulları sağlayan durum yörüngesini $(x(1), \ldots, x(K))$ hesaplamak
  - bağlantılar: Trajectory optimization, Motion planning
- tasarım optimizasyonu (*design optimization*) problemi: tasarım belirtimlerini sağlayan dinamik modeli ve/veya parametrelerini hesaplamak
  - bağlantılar: Design optimization, Multidisciplinary design optimization

Bölüm 5

Uygulamalar

Araç hız sabitleme kontrolü

Figure 4.1: Block diagram of a cruise control system for an automobile

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Yük trenlerinde hız kontrolü

Figure 1.20: Freight train trip optimizer

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İnternet sıkışıklık (*congestion*) kontrolü

Figure 4.12: Internet congestion control

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Atomsal kuvvet mikroskobu

Figure 4.14: Atomic force microscope

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İnsülin-glukoz dinamikleri

Figure 4.19: Insulin–glucose dynamics

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Gürültü bastırma

Figure 5.20: Headphones with noise cancellation

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Otonom araçta ağ bağlantılı kontrol

Figure 1.23: DARPA Grand Challenge. "Alice," Team Caltech's entry in the 2005 and 2007 competitions and its networked control architecture

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Karayolu trafiği akış kontrolü