Contents

1 Introduction

1.1 Typical Sensors and Actuators

- Sensors
  - acceleration sensor
  - light sensor
  - force sensor
  - temperature sensor
  - video camera
  - pressure sensor
  - angle sensor
  - LIDAR
- Actuators
  - electric motor
  - hydraulic/pneumatic cylinder
  - magnetic valve
  - relay
  - heating
  - piezo actuator
  - pump
  - laser

1.2 Model-Based Design

1.2.1 Process

1. Modeling
2. Design
3. Analysis
4. Deployment

1.2.2 Advantages

- Improvement of the product quality
- Handling complexity
- Shorter development times

1.2.3 Concept of Systems

- **System:** Is a set of interacting or independent components that is distinguished from its environment by a system boundary
- **System boundary:** Describes the exchange of a system with its environment via inputs and outputs
- **Subsystem:** System in a system

1.3 Signal Types

1.3.1 Continuous Signals

$$f : \mathbb{R}_0^+ \to \mathbb{R}$$

1.3.2 Discrete-Time Signal

$$f : \mathcal{D} \to \mathbb{R}$$

where $\mathcal{D}$ is a countable set, e.g. $\mathcal{D} = \{t_1, t_2, \dots\}$ or $\mathcal{D} = \mathbb{N}_0$

1.3.3 Discrete-Value Signal

$$f : \mathbb{R}_0^+ \to \mathcal{D}$$

where $\mathcal{D}$ is a countable set, e.g. $\mathcal{D} = \{0, 1\}$

1.3.4 Discrete-Time and Discrete-Value Signal

$$f : \mathcal{D} \to \tilde{\mathcal{D}}$$

where $\mathcal{D}, \tilde{\mathcal{D}}$ are countable sets

1.4 Systems

	Discrete-State System	Continuous-State System	Hybrid System
States/Inputs/Outputs	discrete	continuous	discrete and continuous
Time variable	t_k (discrete)	t (continuous)	t (continuous)
Input variable	$u(t_k) \in \tilde{\mathcal{D}}_1$	$u(t) \in \mathbb{R}$	$u(t) \in \tilde{\mathcal{D}}_1$ or $\mathbb{R}$
Output variable	$y(t_k) \in \tilde{\mathcal{D}}_2$	$y(t) \in \mathbb{R}$	$y(t) \in \tilde{\mathcal{D}}_2$ or $\mathbb{R}$
State vector	$z(t_k)$	$x(t)$	$x(t)$
Equations	$z(t_{k+1}) = Az(t_k) + bu(t_k)$	$\dot{x}(t) = Ax(t) + bu(t)$	$\dot{x}(t) = Ax(t) + bu(t)$
	$y(t_k) = c^T z(t_k)$	$y(t) = c^T x(t)$	$y(t) = c^T x(t)$

1.4.1 Properties

State of a dynamic system

- A state vector x consists of the (smallest) number of variables that need to be specified at the initial time t_0 so that the future behavior is uniquely defined for a given input signal $u(t)$

Static and Dynamic Systems

- **Static System:** No state required
- **Dynamic System:** State required

Time-Invariant and Time-Variant Systems

- **Time-invariant system:** Shift of time does not change the outcome
- **Time-variant system:** Shift of time alters the outcome

Deterministic and Non-Deterministic Systems

- **Deterministic system:** For an initial state $x(0)$ and a given input signal $u(t)$, there exists a unique solution of the state and the output
- **Non-deterministic system:** The evolution of the state and the output is not uniquely determined by the initial state and the input signal

Causal, Acausal, and anticausal Systems

- **Causal sytem:** The output only depends on past and current inputs
- **Acausal system:** The output depends on past, current, and future inputs
- **Anticausal system:** The output only depends on future inputs

Notes

This is a summary of the lecture Cyber-Physical Systems of the Technical University Munich. This lecture was presented by Althoff M. in the summer semester 2020. This summary was created by Gaida B. All provided information is without guarantee.