Statistics and Sensor Data Fusion
Winter Term 23/24

Prof. Dr.-Ing. Gernot Fabeck

Organizational Remarks

- **Seminar-like lectures and exercises:**

  Monday, 08:15 - 09:45, Campus II, 9.E.26

  Thursday, 08:15 - 09:45, Campus I, 5.1.01

- Additionally, there will be **worksheets** for self-study, exemplary solutions are provided with a small delay

- Lecture slides, worksheets and exemplary solutions will be made available via **elearning** under

  `https://elearning.thws.de/course/view.php?id=25049`

  Password: STSE-WS-23

- The **messaging function** of elearning will be used, so please enroll in the course

Organizational Remarks

- **E-Mail:** `gernot.fabeck@thws.de`
- **Consultation Hours:**

  Monday, 12:00 - 13:00, room 1.E.43 (Campus I)
- **Examination:** Written exam of 90 minutes duration
- **Permitted Examination Aids:**
  - Three handwritten A4-sheets (two-sided, no copy)
  - Non-programmable pocket calculator

Literature

Statistics:

Diez, Çetinkaya-Rundel, Barr: OpenIntro Statistics. 4th edition, OpenIntro, 2023. available online for free

exercises

Spiegel, Schiller, Srinivasan: Schaum's Outline of Probability and Statistics. 4th edition, New York, McGraw-Hill, 2013. THWS Library

examples

Sullivan: Fundamentals of Statistics – Informed Decisions Using Data. 5th edition, London, Pearson Education, 2017. THWS Library

Sensor Data Fusion:

Koch: Tracking and Sensor Data Fusion – Methodological Framework and Selected Applications. Berlin, Springer Verlag, 2014.

Ma, Yan, Xia, Fu: Kalman Filtering and Information Fusion. Singapore, Springer & Science Press, 2020.

Mitchell: Data Fusion – Concepts and Ideas. 2nd edition, Berlin, Springer Verlag, 2012.

Introduction and Overview

Scope of the Course

- We will deal with standard statistical methods from a toolbox perspective (i.e. no proofs)
- The key learning objective is the ability to identify suitable statistical methods for given real-world problems
- Effective use of these methods in real-world applications will usually require the use of computer software like e.g.
  - Excel
  - Matlab
  - Python
  - R

  which is no explicit part of the course

What is Statistics?

https://www.mathnasium.com

What is Statistics?

- "Statistics is the science of learning from data, and of measuring, controlling and communicating uncertainty." *American Statistical Association (ASA)*
- "Statistics is a collection of concepts and methods to analyze mass appearances."
- "Statistics is a way to get information from data."

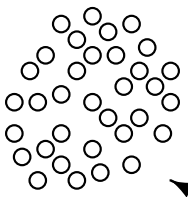
The **main branches of statistics** are

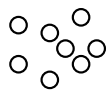
- descriptive statistics
- probability calculus
- inductive statistics

Descriptive Statistics, Probability Calculus and Inductive Statistics

Probability Calculus

Goal: Mathematical treatment of random phenomena

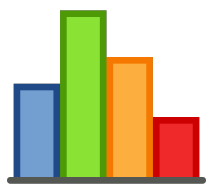




Data Sample

Descriptive Statistics

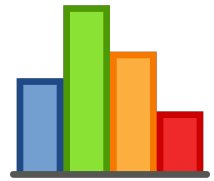
Goal: Suitable graphical and numerical representation of the data



Inductive Statistics

Goal: To infer properties of an underlying population

Descriptive Statistics



- Descriptive statistics aims at revealing the meaningful features of a collection of data at hand by suitable **graphical or numerical representations**
- Often this refers to condensing a huge amount of raw data into a **few relevant indicators**
- **No statements** are made beyond the data
- **Examples:**
  - The annual inflation rate in the eurozone is 5.3 % (August 2023)
  - Currently, the fraction of international students at THWS is about 30 %
  - The average grade in the last exam was 2.89

Probability Calculus

- Probability calculus or probability theory can be considered as the **mathematics of chance**
- Based on a few first principles, probability calculus facilitates the consistent analysis of **random phenomena**
- The axiom system of modern probability theory was presented by **Andrey Nikolaevich Kolmogorov** in 1933
- **Examples:**
  - The probability for tossing heads three times in a row when flipping a fair coin is

$$\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} = \frac{1}{8} = 0.125$$

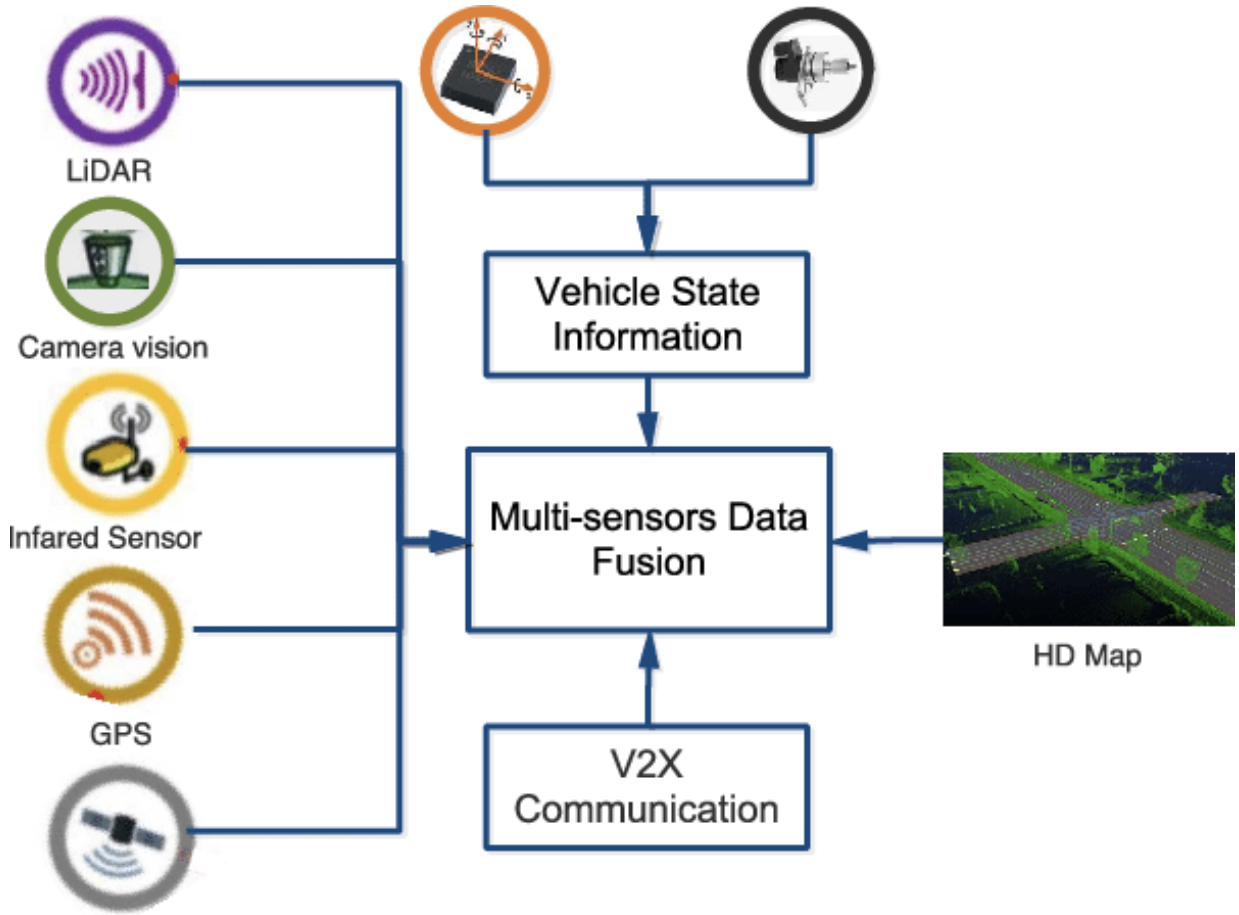
  - The probability to win in the national lottery 6 out of 49 is

$$1 : \frac{49!}{6! \cdot 43!} = 1 : 13\,983\,816 = 0.0000000715112384$$

Inductive Statistics

- Inductive or inferential statistics interprets the data as a **random sample** drawn from a larger population
- Based on the data sample, **inferences** are made about properties of the usually unknown population
- In order to assess the quality of these inferences, the application of **probability theory** is necessary
- **Examples:**
  - What can be concluded from the outcome of a quality test on the subset of a delivery about the delivery as a whole?
  - What might be the probable trajectory of an object based on previous measurements?

What is Sensor Data Fusion?



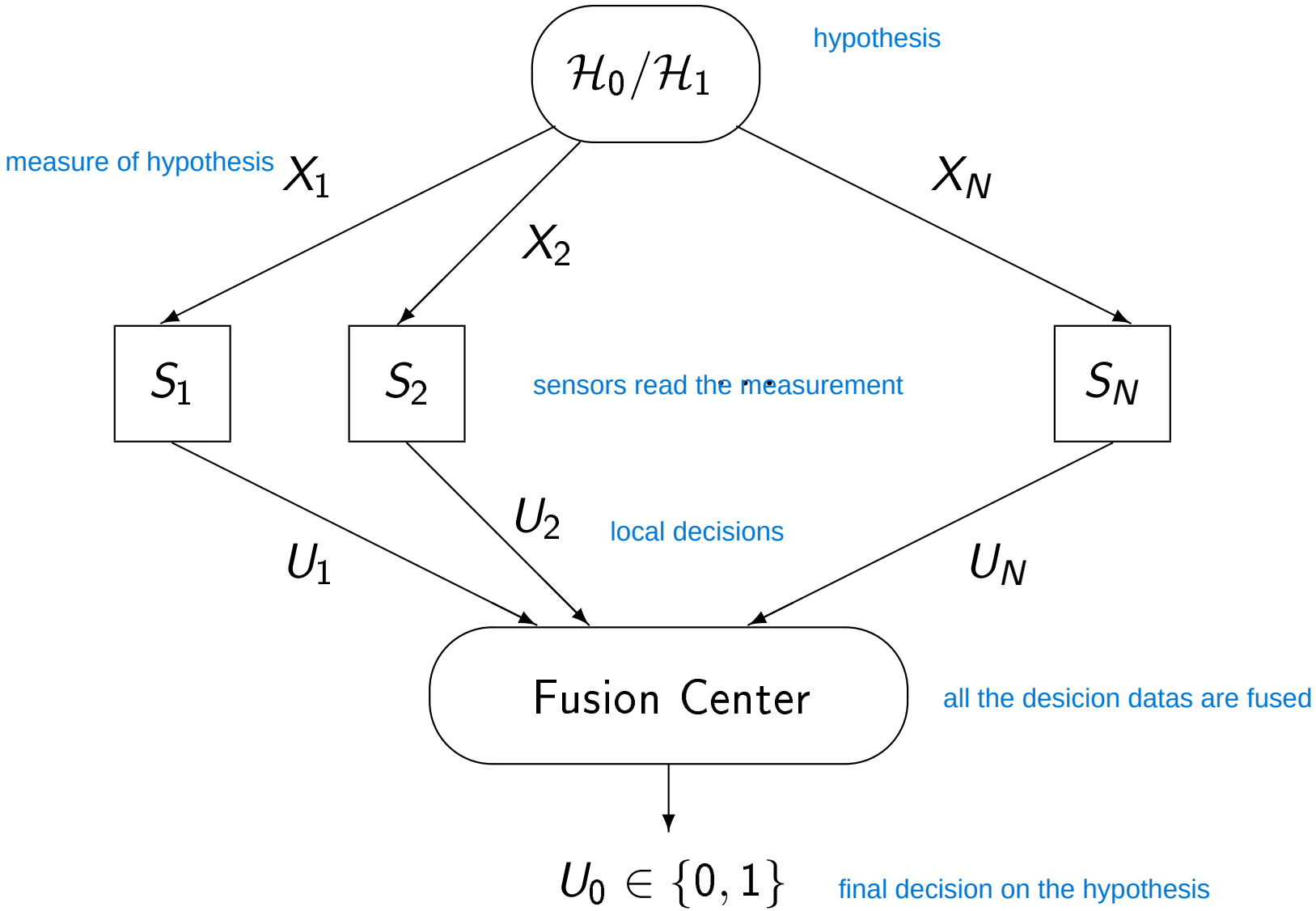
Fu, Yuchuan & Li, Changle & Yu, Fei & Luan, Tom Hao & Zhang, Yao. (2021). A Survey of Driving Safety With Sensing, Vehicular Communications, and Artificial Intelligence-Based Collision Avoidance. IEEE Transactions on Intelligent Transportation Systems. PP. 1-22. 10.1109/TITS.2021.3083927.

What is Sensor Data Fusion?

- Sensor data fusion is the process of **combining information from multiple sensors** to achieve inferences that are more accurate than that provided by any individual sensor
- The fusion of information from sensors with different physical characteristics enables or enhances the understanding of the environment and thus provides the basis for **autonomous and intelligent machines**
- Fusion processes are often categorized as **low**, **intermediate**, or **high**, depending on the processing stage:
  - Data Fusion: Combination of several sources of raw data
  - Feature Fusion: Combination on feature level
  - Decision Fusion: Combination of several decisions

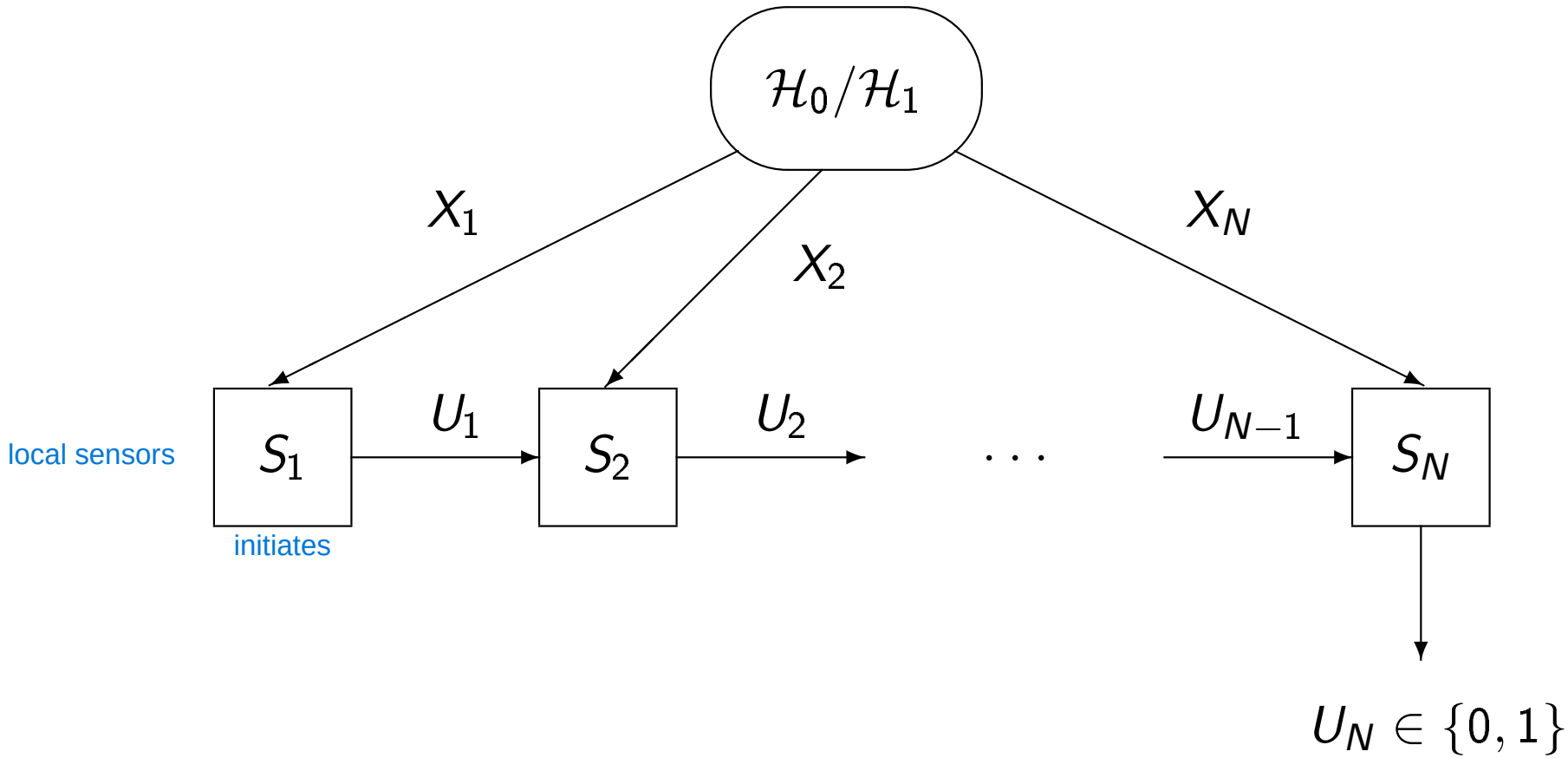
Decision Fusion – Example

Parallel Fusion Network:



Decision Fusion – Example

Serial Network:



Outline of the Course

1. Descriptive Statistics
2. Probability Calculus
3. Pattern Recognition and Bayes Optimal Classifier
4. Inductive Statistics
5. Sensor Data Fusion – Introduction and Overview
6. The Kalman Filter