Data Analytics for Cyber-Physical Systems: Automatic Failure Diagnosis

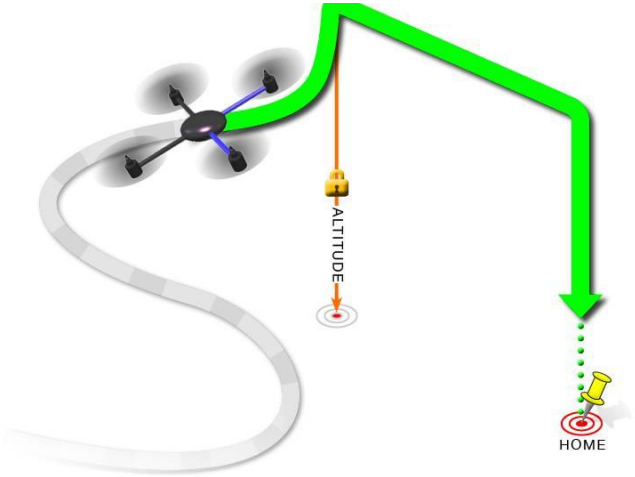
Master-Praktikum: IN2106
Winter semester 2020/21
Instructor: Ehsan Zibaei

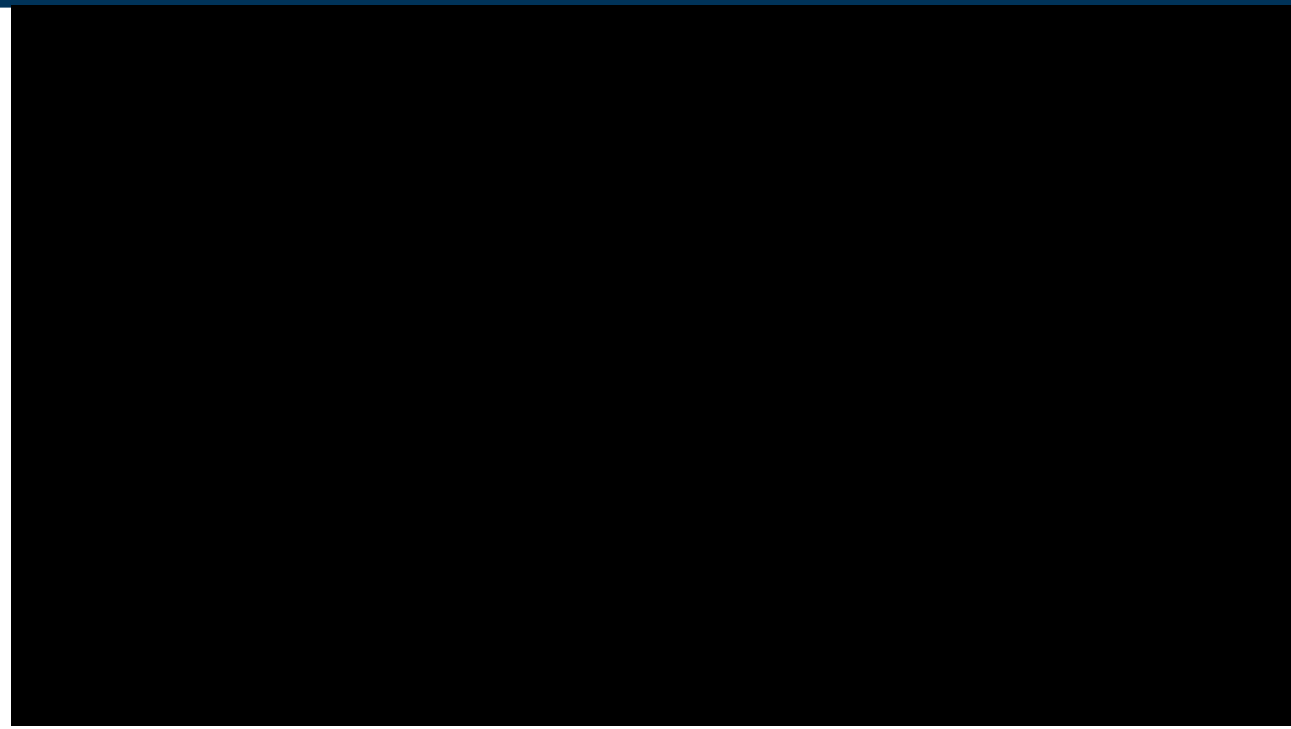
Cyber-physical Systems

- **Cyber-physical systems** consist of a collection of computing devices communicating with one another and interacting with the physical world via sensors and actuators in a feedback loop
- **Examples** are drones, autonomous cars, robotic arms, etc.

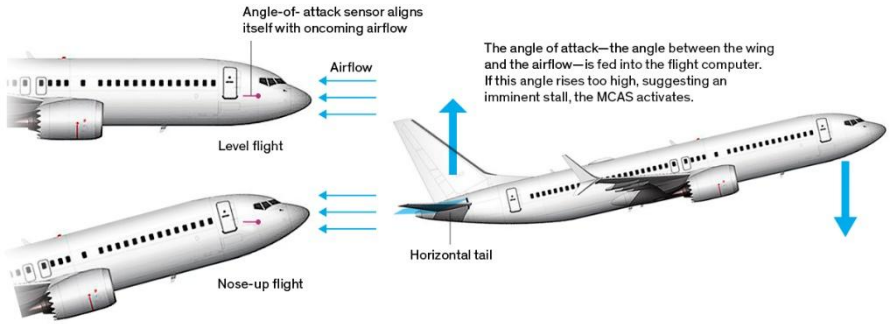
Safety accidents

- Drone crashes
  - Sensor failure
  - Actuator failure
  - SW bug





- Lion Air 737 MAX crash



Source:
https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer

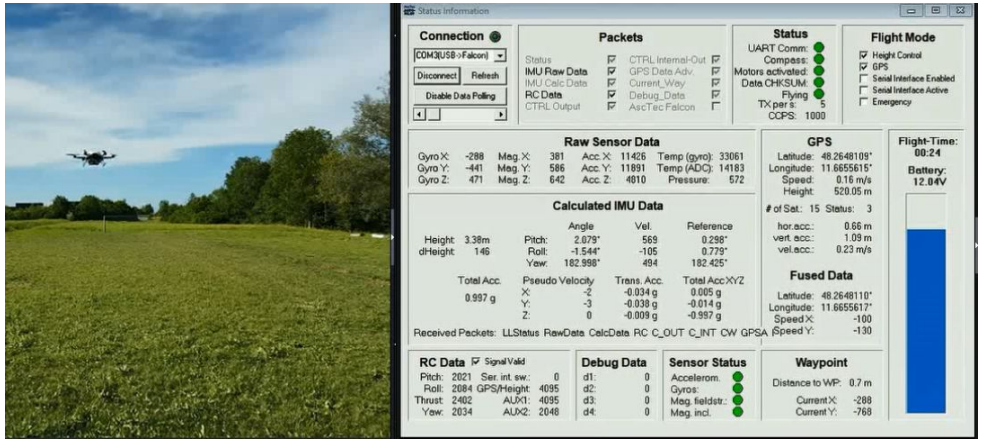
```
// if we have gps lock, attempt to hold horizontal position
if (GPS_ok()) {
    // switch to loiter which restores horizontal control to pilot
    // To-Do: check that we are not in failsafe to ensure we don't process bad roll-
    set_roll_pitch_mode(ROLL_PITCH_LOITER);
    // switch into loiter nav mode
    set_nav_mode(NAV_LOITER);
}else{[/code]
```

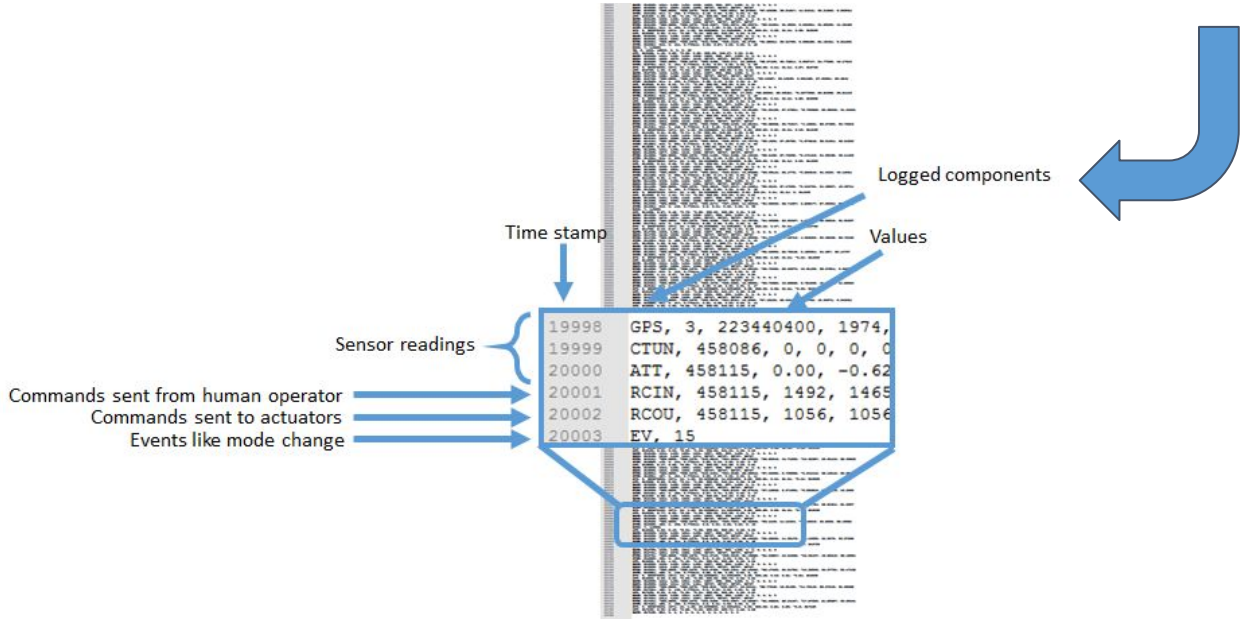
Improving safety

- Preventive approach
  - Testing, model checking, static analysis
- Detective approach
  - Post mortem data analysis

Improving safety by Data Mining

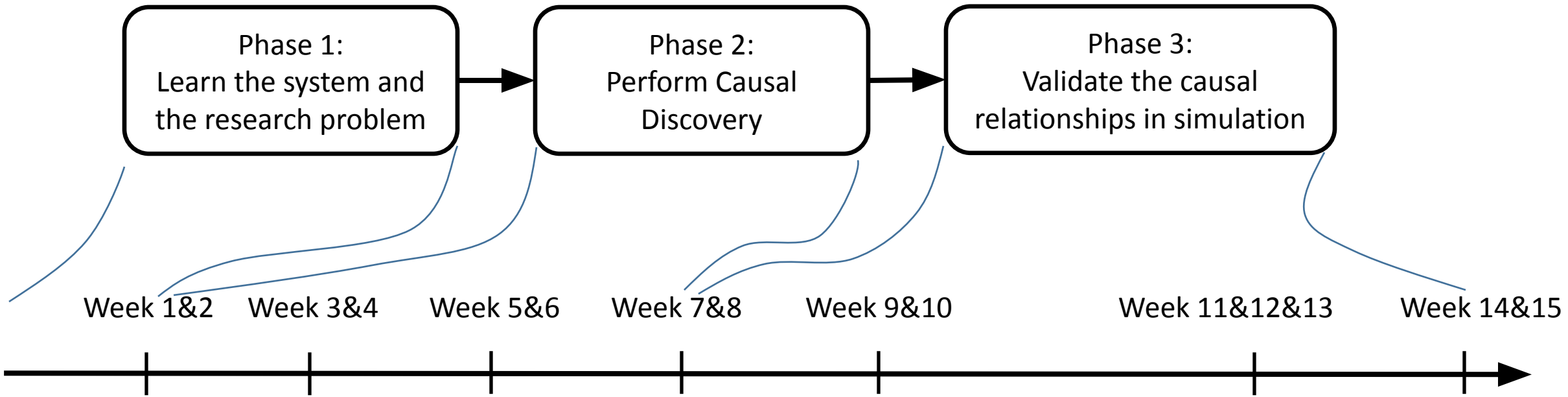
- Why data is important
  - Data can explain the causes of the incident without a model
  - Vast amount of data is produced and available





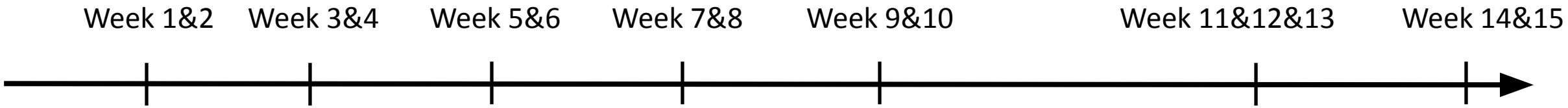
Course plan

- Work flow
- Phases
- Biweekly plan



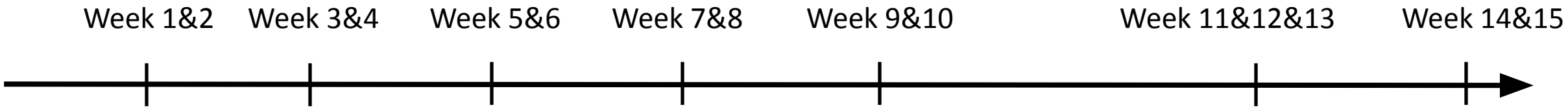
Course plan

- Tasks
  - Every week, teams will submit a one page report including
    - What did each member do (including Gitlab commits) in the past week?
    - What impediments did each member encounter in the past week?
    - What each member is going to do in the next week?
  - Every two weeks teams will present the last status of their work
  - Teams will keep their Gitlab repository up to date



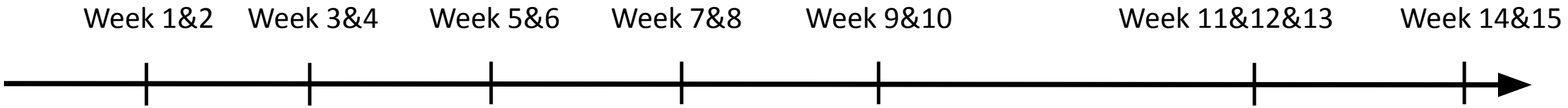
Course plan

- Week 1 & 2
  - System understanding
    - Read about normal and abnormal behavior of components
    - Read about meaning of events in drones
  - Research understanding
    - Read about causal discovery algorithms
  - Data preparation
    - Prepare a dataset with ~25000 flight log instances



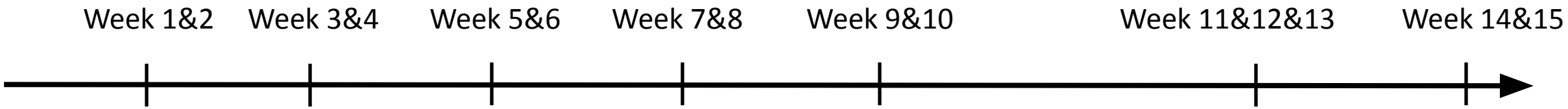
Course plan

- Week 3 & 4
  - Implement a causal discovery algorithm or use available tools
    - SGS algorithm
    - PC algorithm
    - FCI algorithm
    - *pcalg* of ETH or *Tetrad* of CMU
  - Run causal discovery algorithms on the data



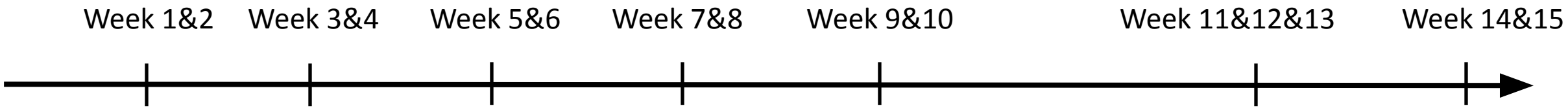
Course plan

- Week 5 & 6
  - Evaluate robustness, performance
    - Which algorithms are faster?
    - Did you use any heuristic to improve the performance?
    - Are the outputs of the algorithms robust against cross-validation?



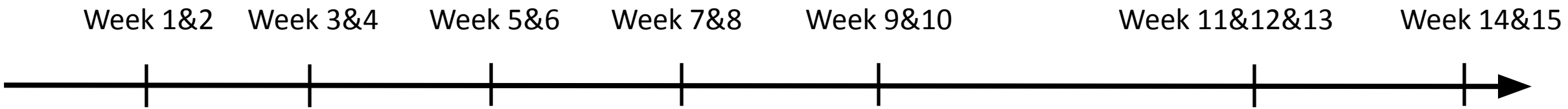
Course plan

- Week 7 & 8
  - Install the simulation environment
  - Identify how to inject faults and record simulation results



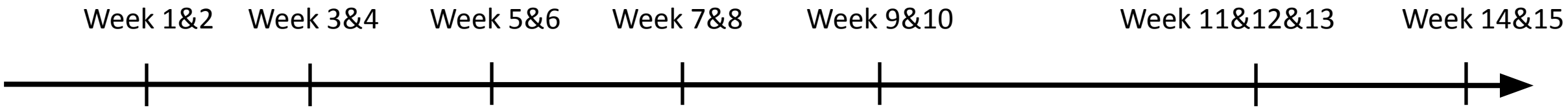
Course plan

- Week 9 & 10
  - Read about counterfactual analysis
  - Evaluate effectiveness of the causal discovery by experimenting in the simulation



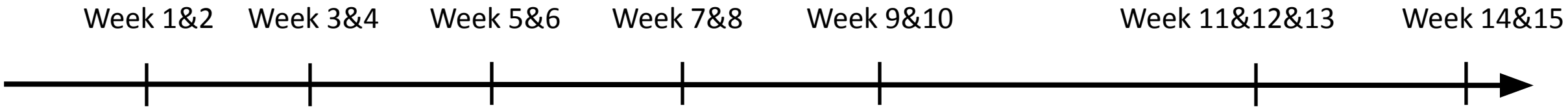
Course plan

- Week 11 & 12 & 13
  - Read about '*Fault Tree Analysis*' and '*Failure Modes and Effects Analysis*'
  - Use outputs of causal discovery to build such models



Course plan

- Week 14 & 15
  - Finalize the results
  - Submit the final report in LNCS format
  - Prepare and present the final presentation



Course description

- Highlights
  - Hands-on experience with real data from drone crashes
  - Learn causal discovery algorithms
  - Learn safety analysis for robotic systems

- Requirements
  - Proficiency in Python and its fundamental data science libraries such as Pandas, Numpy, and Matplotlib
  - Proficiency in Robot Operating System (ROS) and Gazebo simulator
  - Dedication and enthusiasm!

Important to remember

- Registration: Using the matching system
  - http://matching.in.tum.de
- Fill in this questionnaire: https://forms.gle/pj9L615tmma5ers77 for better matching
- Language: English
- Only M.Sc.
- Max. members: 10 working in 2-person groups
- Sessions:
  - Once every two weeks
  - Starting from 14.10.2019 (Wednesdays)
  - Time: 15:00 - 17:00
  - Place: Seminarraum (5609.01.014)

Further questions:
zibaei@in.tum.de