Lecture

Organic Computing II

Summer term 2019

Chapter 4: Observer/Controller Architecture

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Agenda

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Content

- General design concept for organic systems
- Observer/Controller architecture
- Multi-level Observer/Controller framework
- Conclusion and further readings

Goals

Students should be able to:

- Outline the basic design concept used in OC.
- Sketch the Observer/Controller approach and the multi-level extension.
- Compare distribution variants.
- Explain the responsibilities of the contained components.

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- General design concept for organic systems
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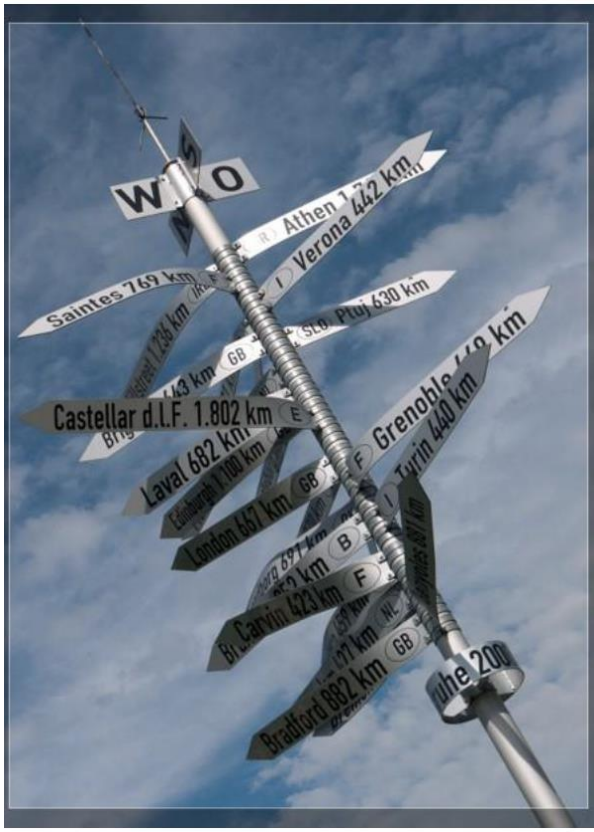

General concept of an organic system

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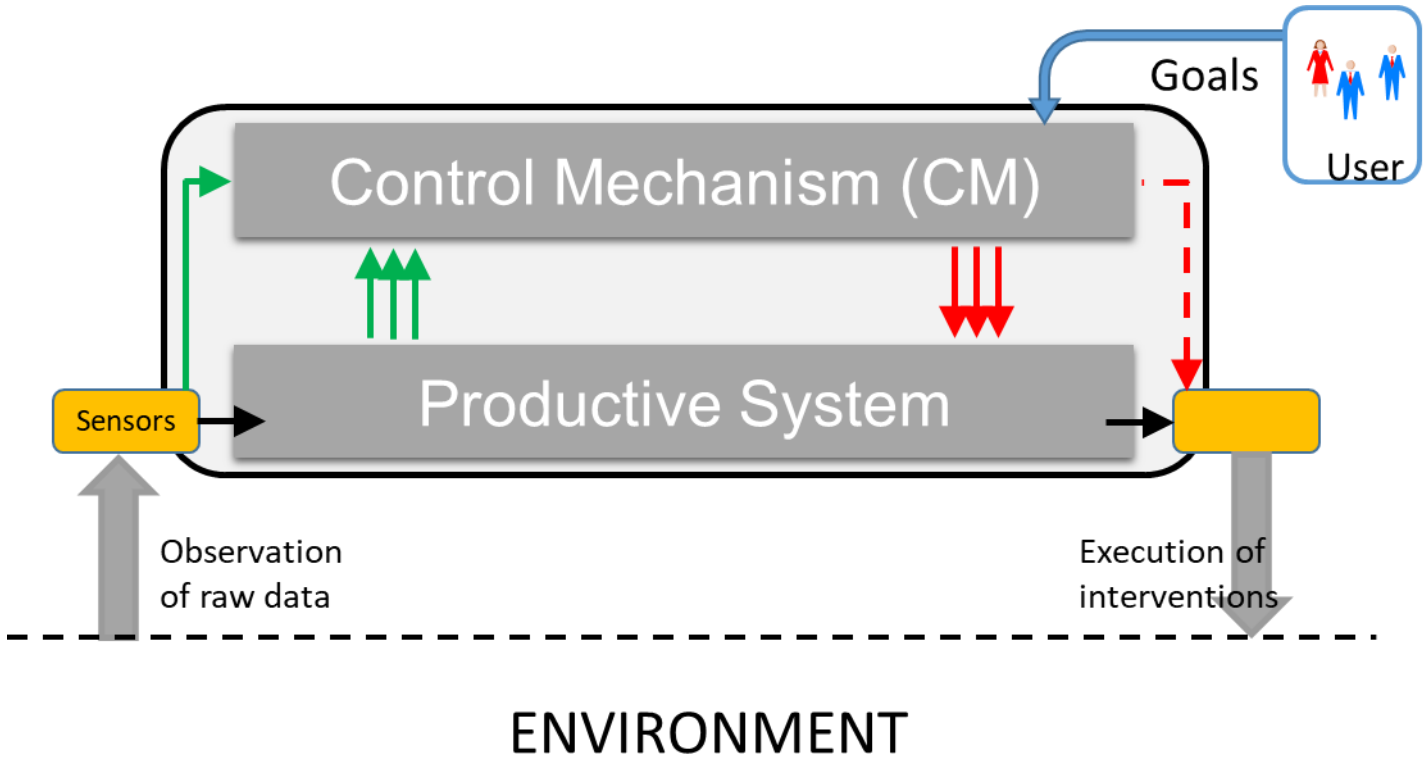

Green: flow of observed data
Red: flow of control interventions

General concept of an organic system (2)

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System boundaries

- Everything not directly related to the system itself is modelled as being part of the external environment.
- Environment is accessed through sensors and manipulated by actuators.

Take the human operator “out of the loop“

- Productive system is only influenced by internal control mechanism.
- Theoretical possibility for the user to intervene directly with the output signal.
- User provides just a goal (or a set of goals) defining good or bad behaviour.
- CM figures out what to do in which situation without direct human intervention.
- Classic approach: user specifies directly what the system has to do.

General concept of an organic system (3)

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Requirements

- Access to sensor readings covering all important aspects.
- Access to internal status variables of productive system.
- Utility function specifying good/bad behaviour.
- Access to control interfaces of productive system.
- Control interface has to be directly related to performance.

Actions

- Manipulation of parameters to guide behaviour of productive system.
- Activation or deactivation of components and functionality.
- Exchange of algorithms or techniques in use.
- Selection of interaction partners.
- Modification of observation model (i.e. selection, resolution, and frequency of sensor information)

General concept of an organic system (4)

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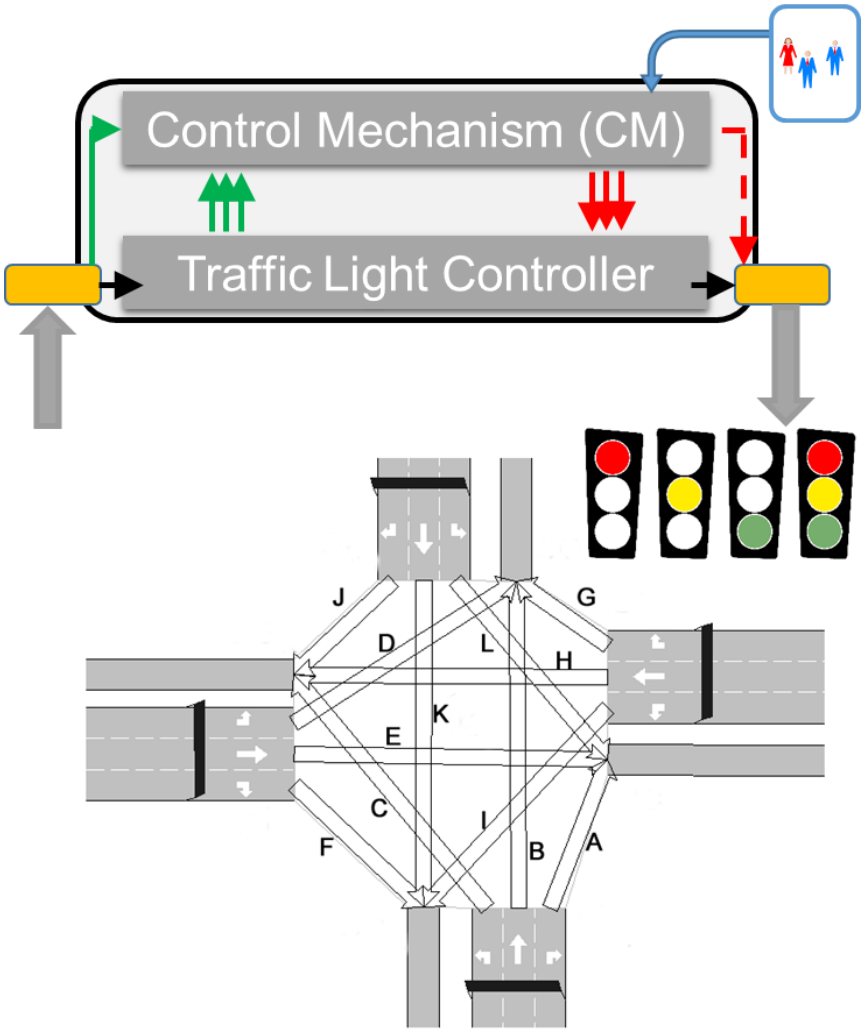
Example: Traffic control

- Productive system: traffic light controller
- Sensor readings: induction loop readings (occupied or not)
- Effectors: traffic signals (green/yellow/red)
- Input CM: vector with traffic flow per hour for each turning
- Output CM: green durations for each traffic light



General concept of an organic system (5)

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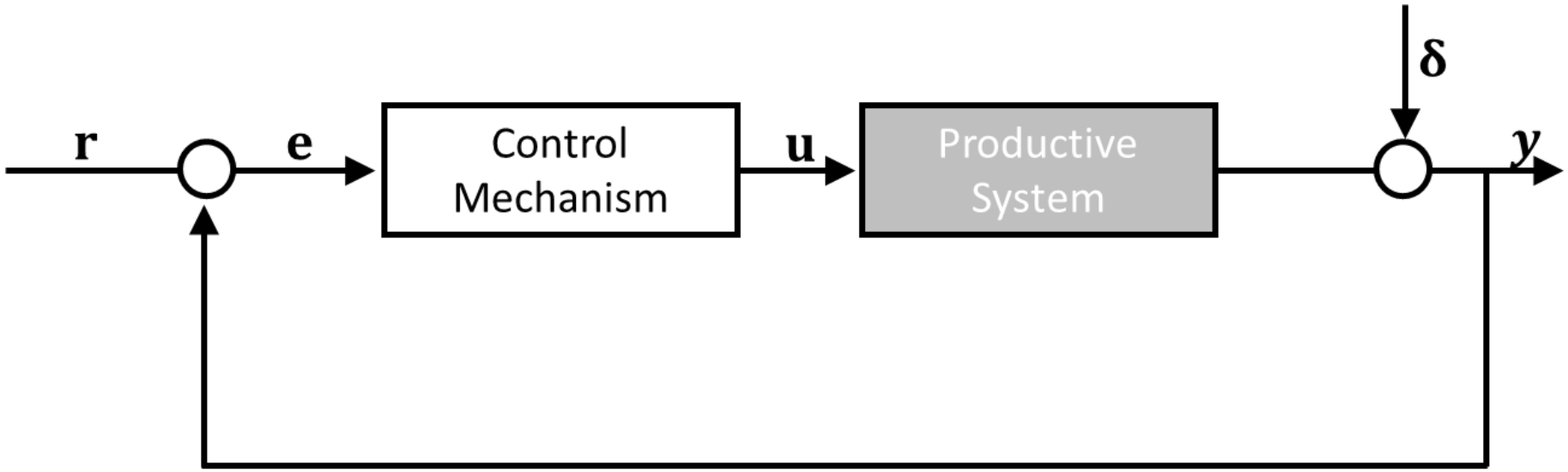
Control loop

- Actions have impact on performance
- Performance is measured from the environment
- Environment is modified by actions
  → Feedback loop (see control theory)



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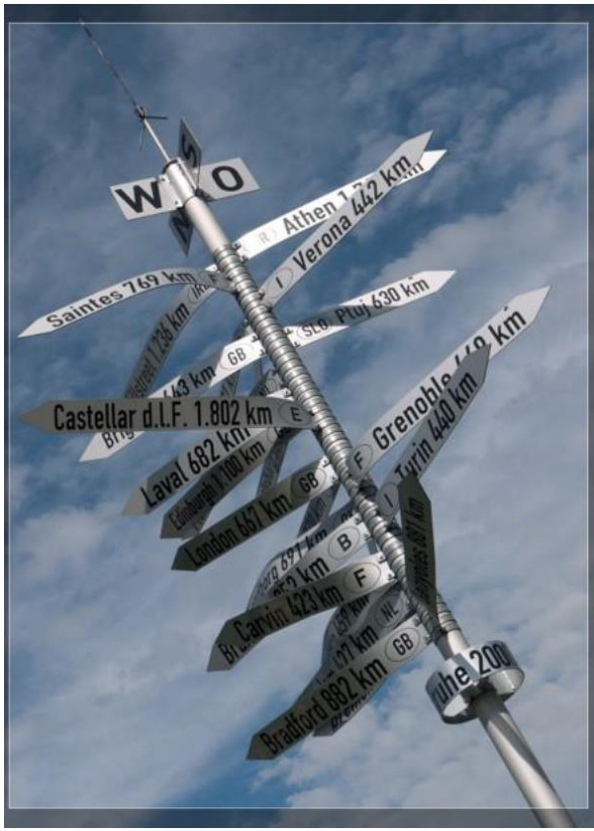
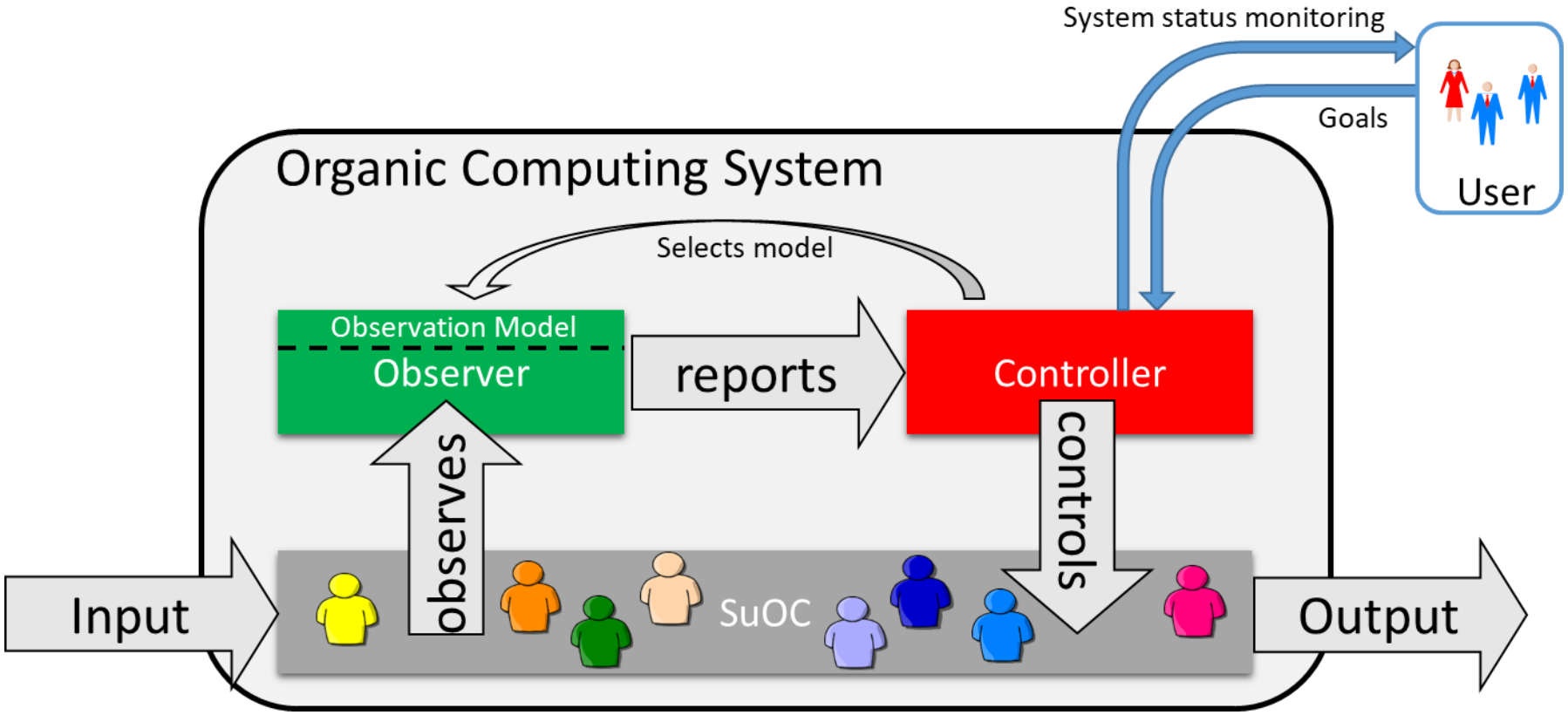


Generic observer/controller pattern



Generic observer/controller pattern (2)

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Three major components:

- System under Observation and Control (SuOC):
  - Productive part of the system
  - Functional even if higher-layered observer/controller components fail
  - Not restricted to individual devices
- Observer:
  - Gathers information
  - Analysis, predicts, detects patterns
  - Builds situation description
  - Based on observation model
- Controller:
  - Decides about actions
  - Learns from feedback
  - Modifies observation model

Generic observer/controller pattern (3)

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Learning from feedback

- Rule-based system
- Rule:

  [Condition] [Action] [Evaluation]
- Rules compete, more than one can fulfil condition
- Evaluation criteria used to decide which to take, updated in each cycle

Traffic example

- Condition: vector with intervals for traffic flows per hour per turning
- Action: Green durations per traffic light
- Evaluation: Averaged delays occurring at intersection

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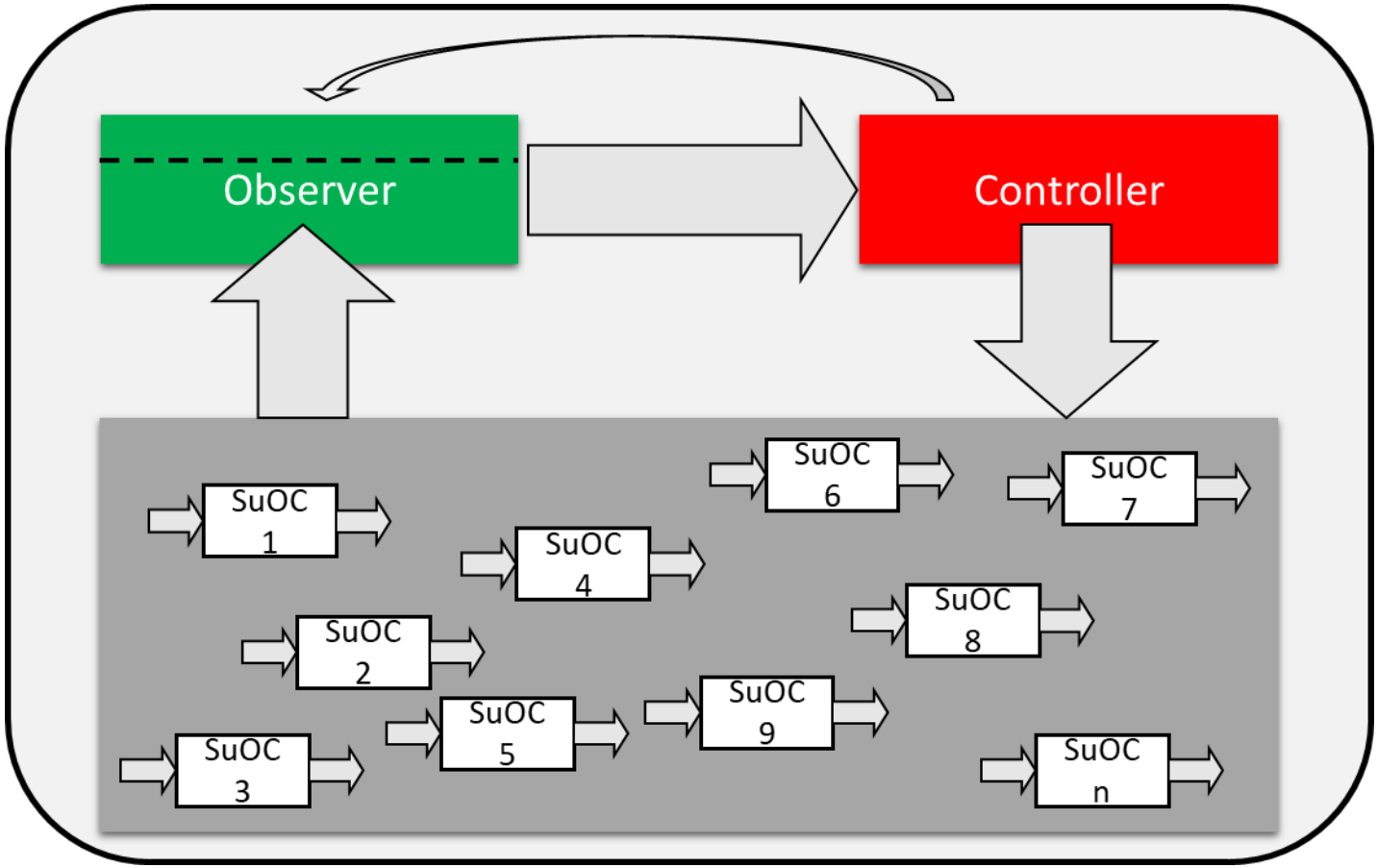
Variant A: Fully centralised



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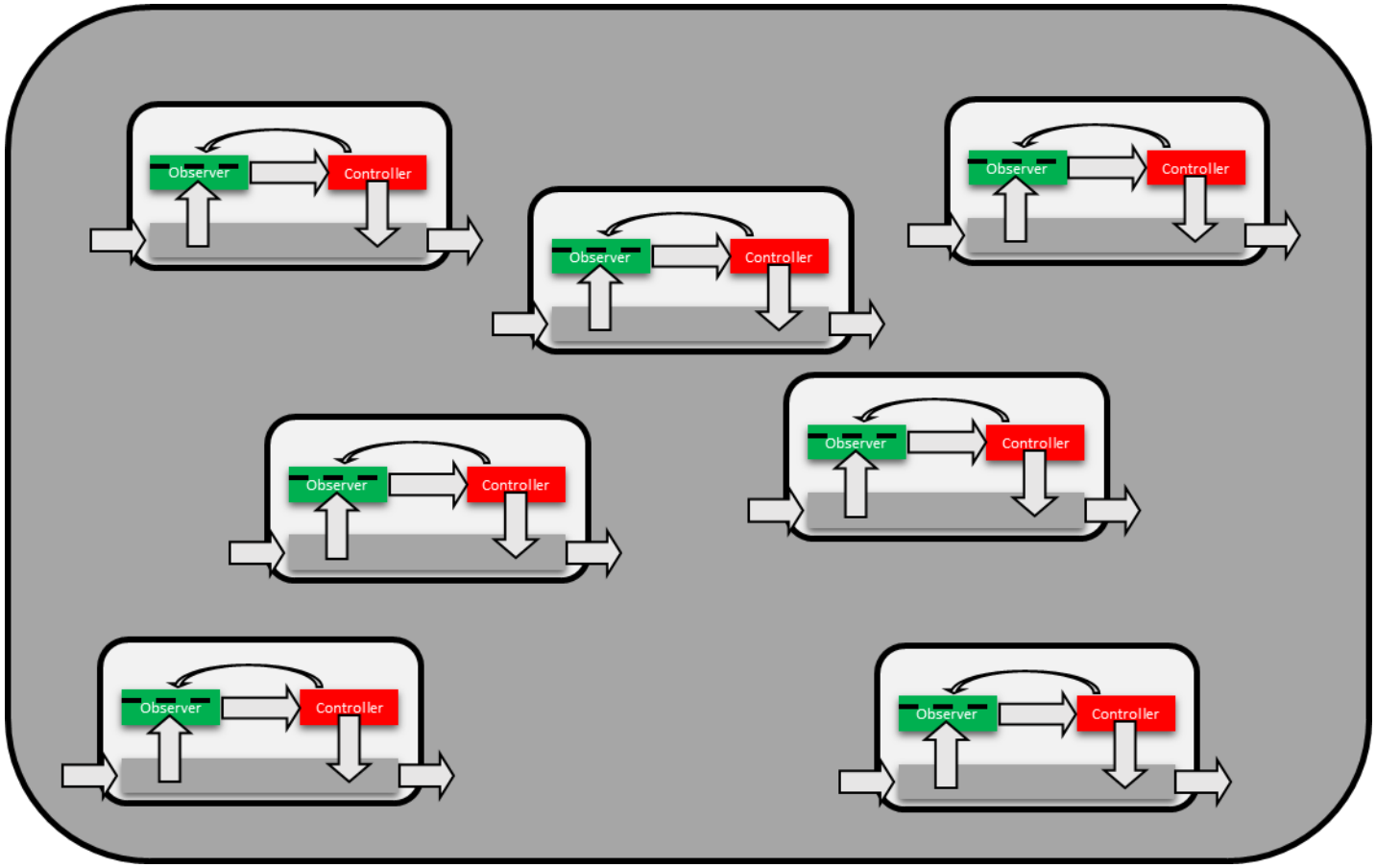
Variant B: Fully decentralised



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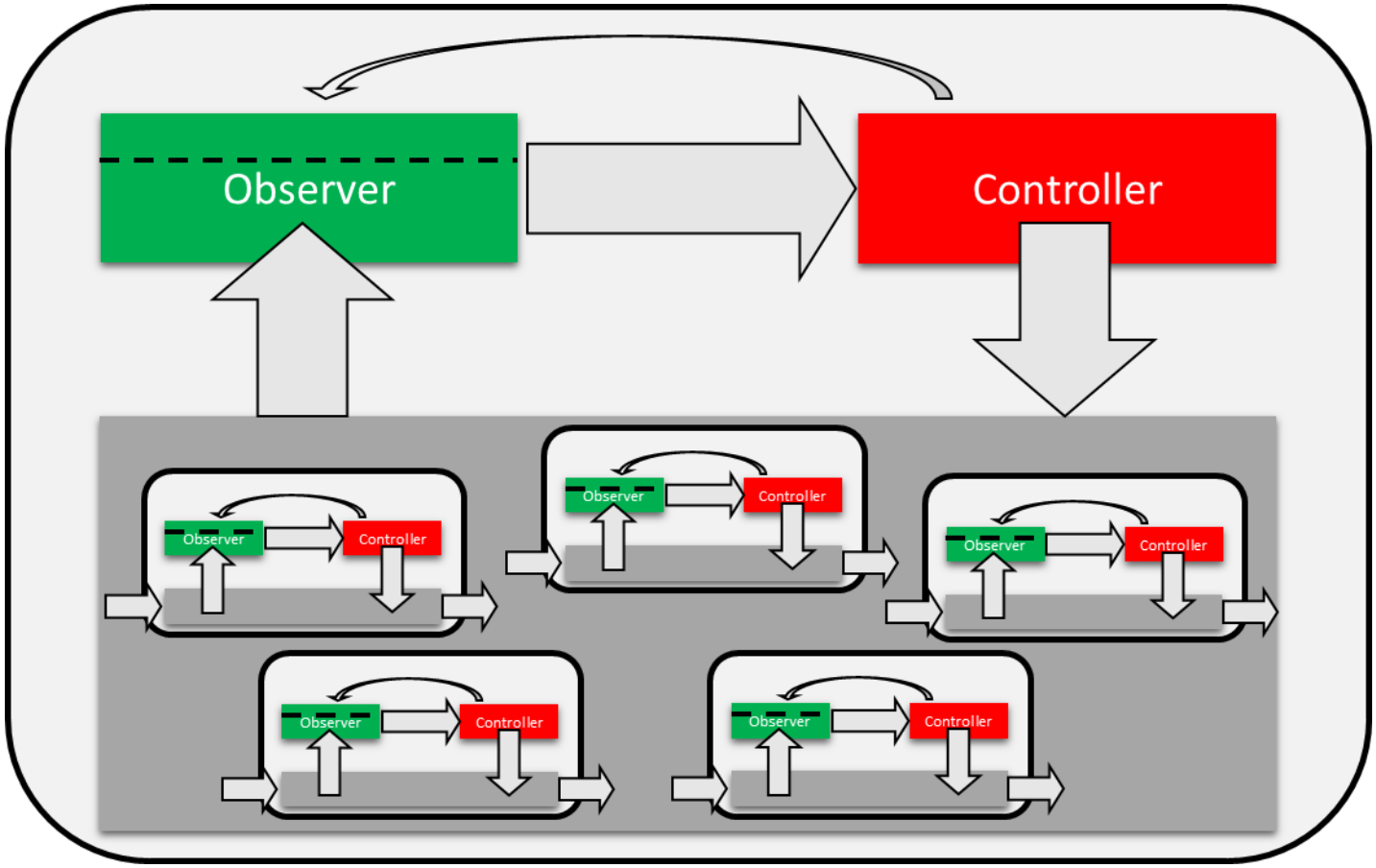
Variant C: Hybrid



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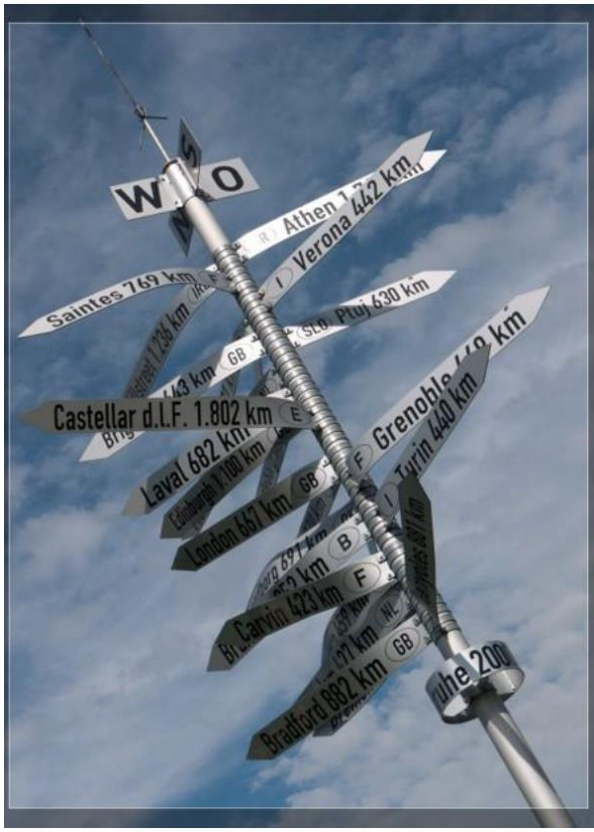
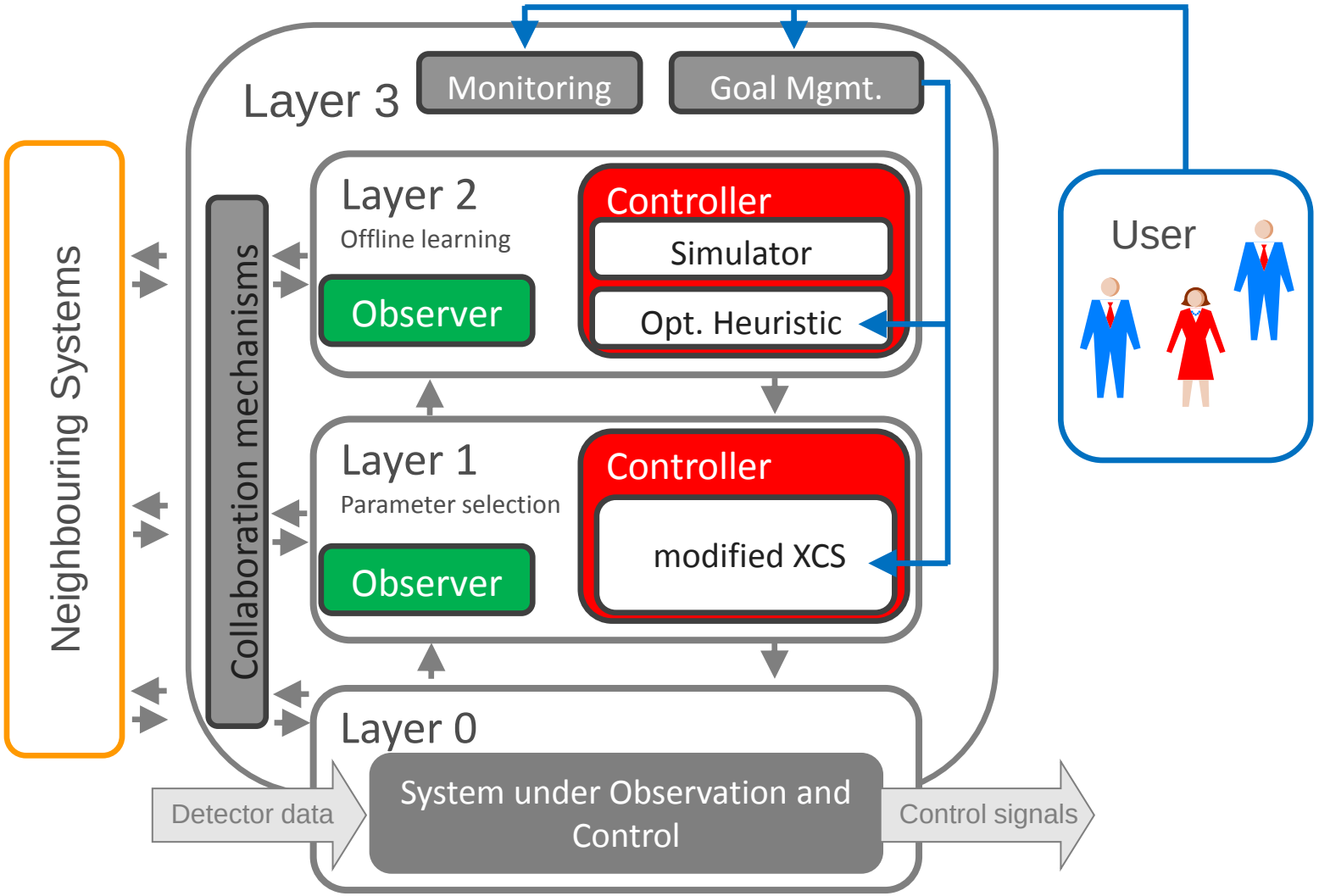


Multi-level observer/controller framework



Multi-level observer/controller framework (2)

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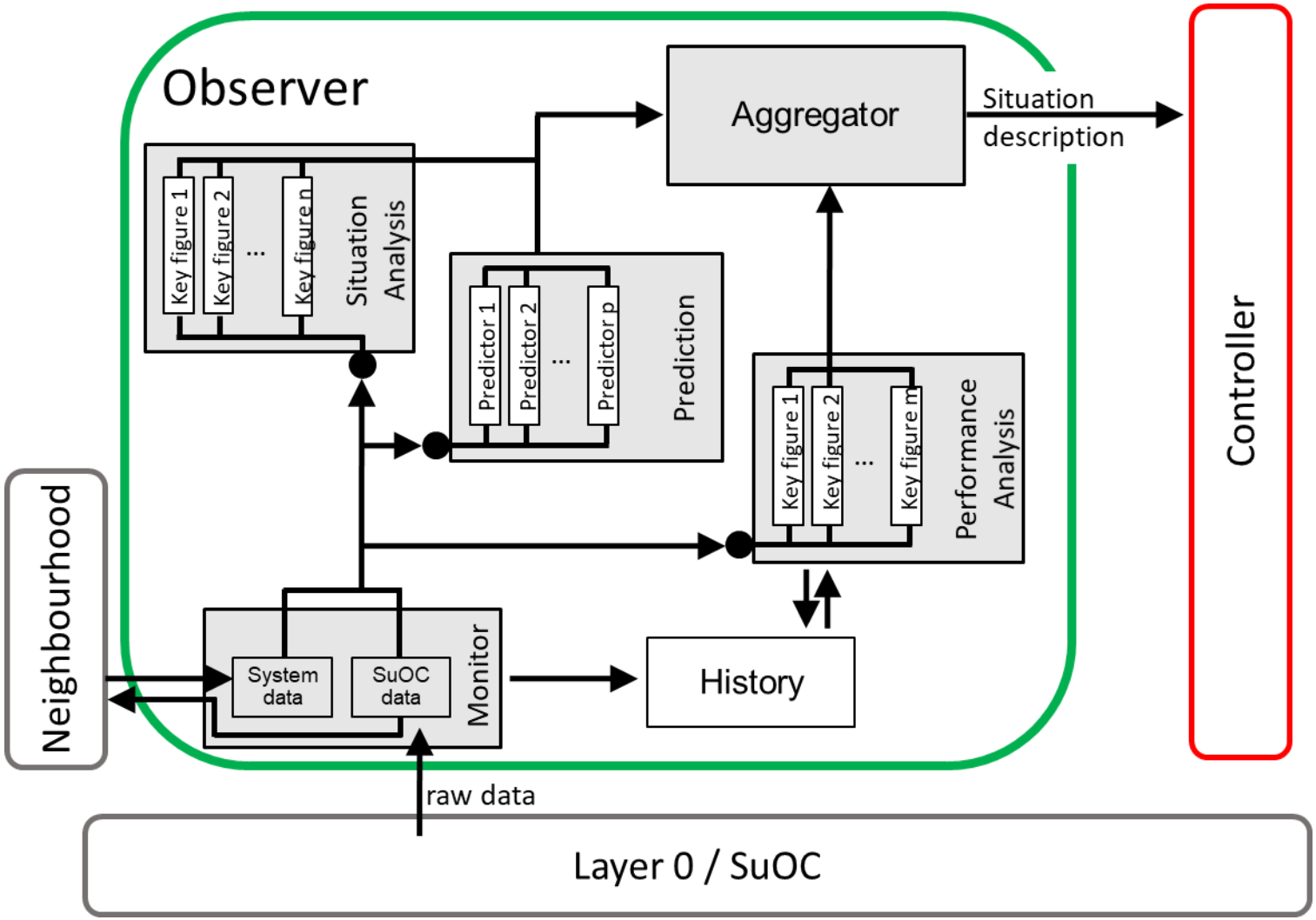
- Layer 0: Productive system
  - Encapsulation of the SuOC
  - Provide access to observation and control interfaces
- Layer 1: Parameter selection and online learning
  - Observation of Layer 0:
    - Monitoring, pre-processing, data analysis, prediction, aggregation
    - Generation of situation description
  - Control:
    - Change parameters, structure, techniques to current conditions.
    - Select from existing rule-set, update [Evaluation] based on feedback.
- Layer 2: Offline learning
  - Observation of Layer 1: Missing or inappropriate knowledge
  - Control: Generate new rule, add to rule-based of Layer 1
- Layer 3: Collaboration
  - User: Self-explanation, goal modification
  - Other systems: Negotiation, communication, trust, …

Observer component at Layer 1



Observer component at Layer 1 (2)

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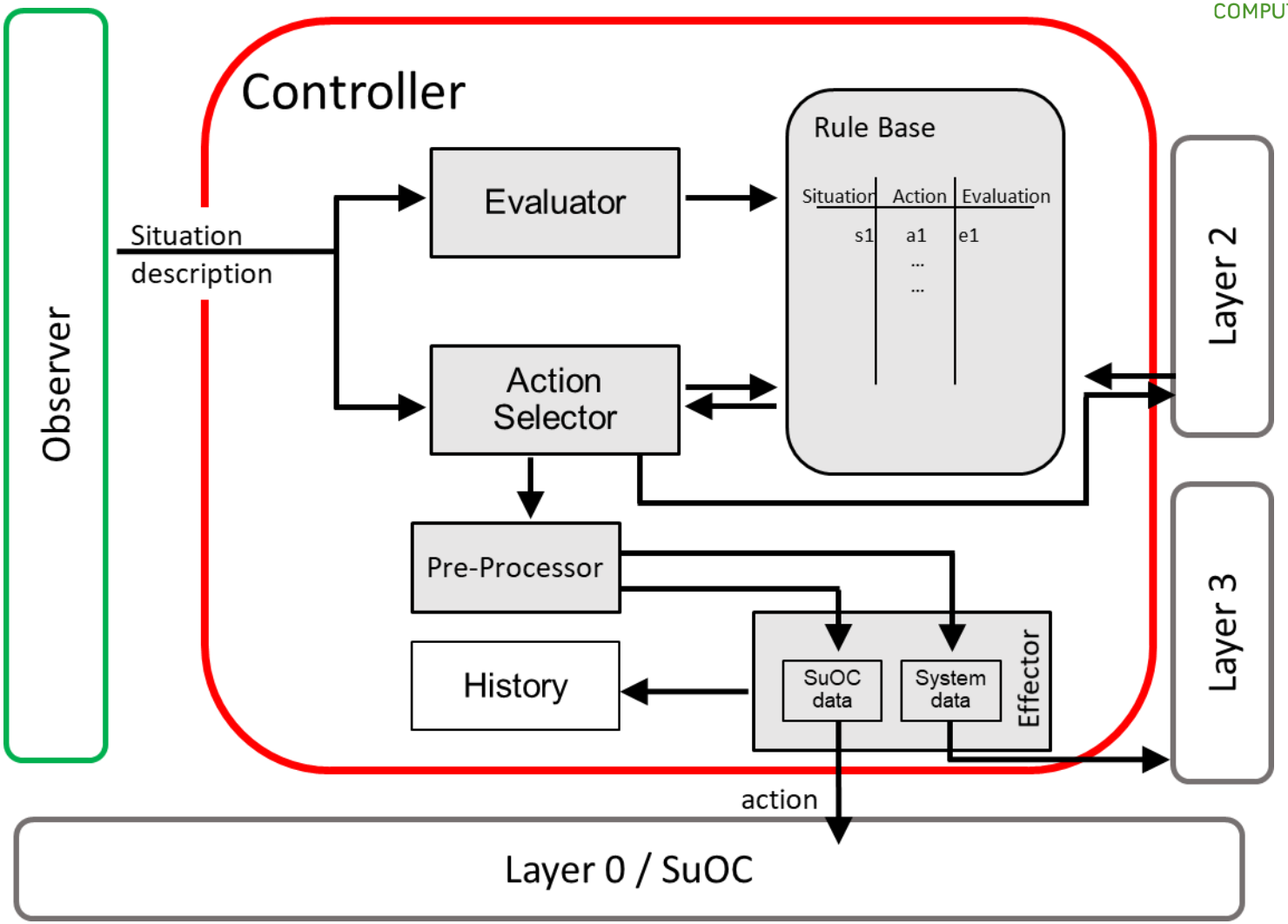
Components:

Observer

- Monitor: Gather sensor and status data
- Pre-processing: Estimate missing values, delete wrong values, smoothing, etc.
- Prediction: Forecasts for some of the underlying values
- Situation analysis: Find patterns, detect emergence, etc.
- Performance analysis: Extract values related to goals
- Aggregator: Build situation description
- History: List of observed data (for debugging and explanation)

Controller component at Layer 1



Controller component at Layer 1 (2)

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Components:

Controller

- Rule base: Set of rules, knowledge of the system
- Action selection: Select rule, action is encoded
- Effector: Activate action via effectors
- Evaluator: Determine success of last action(s), update rules
- Action history: List of situation-action mapping that have been performed

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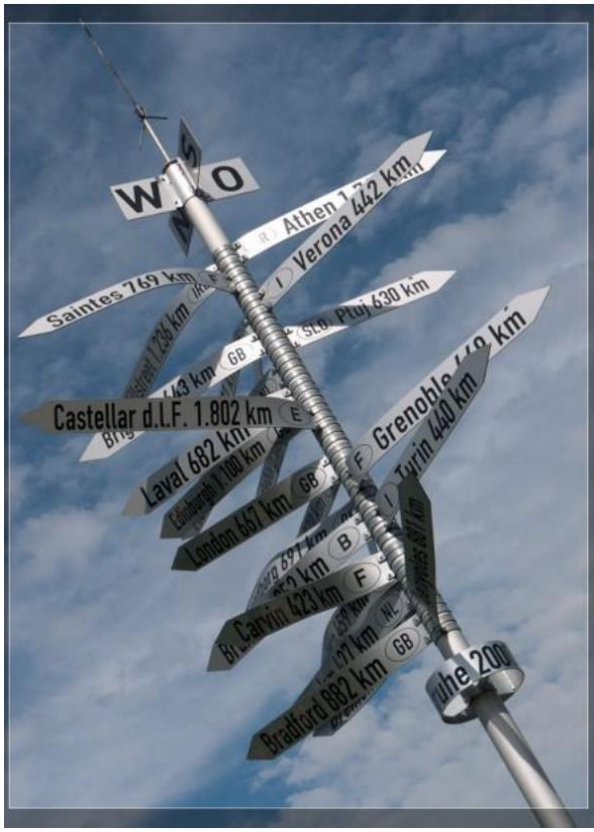

Conclusion

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This chapter:

- Introduced the basic design ideas used in organic systems.
- Refined these concepts by explaining the Observer/Controller approach.

By now, students should be able to:

- Outline the basic design concept used in OC.
- Sketch the Observer/Controller approach and the multi-level extension.
- Compare distribution variants.
- Explain the responsibilities of the contained components.

References

- Christian Müller-Schloer, Hartmut Schmeck, Theo Ungerer: „Organic Computing - A Paradigm Shift for Complex Systems“. Springer 2011
- Sven Tomforde: “Runtime adaptation of technical systems”. Südwest-deutscher Verlag für Hochschulschriften, ISBN-13: 978-3838131337, 2012.

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Questions …?