Bridging the controller design-implementation gap for image-based control systems

Bridging the Controller Design-Implementation Gap for Image-based Control Systems

SAJID MOHAMED*, DIP GOSWAMI*, TWAN BASTEN*^
{s.mohamed, d.goswami, a.a.basten}@tue.nl
*Electronic Systems Group, Eindhoven University of Technology; ^ESI, TNO, The Netherlands

1. Image-based Control (IBC)

- IBC systems are a class of data-intensive feedback control systems whose feedback is provided by image-based sensing [1].

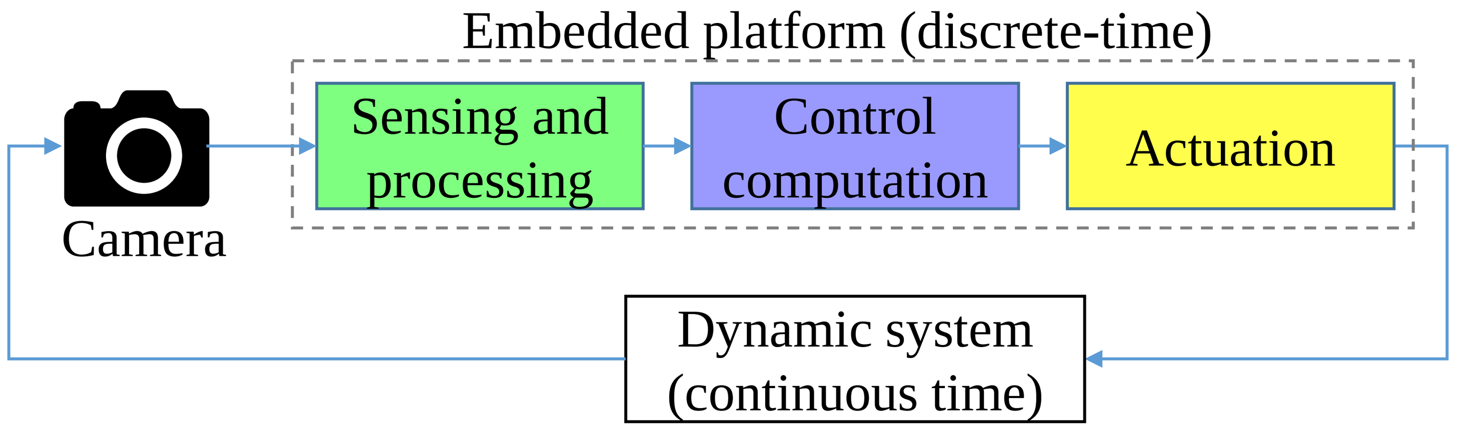

Figure 1. An image-based control system: block diagram

- Here, the sampling period (h) and the sensor-to-actuator delay (τ) is greater than the frame arrival duration (see Fig. 2) , i.e. $h > fps^{-1}$. fps denotes the camera frame rate per second.

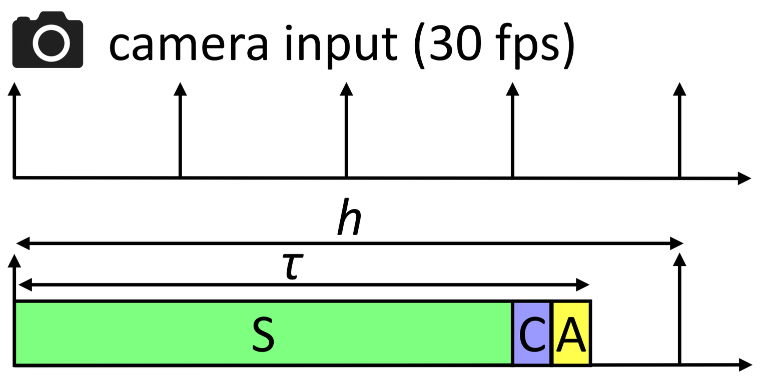

Figure 2. IBC system gantt chart

3. Bridging The Gap

Can we jointly optimise control performance and platform resource utilisation considering workload variations?

4. Approach

- We propose a structured Scenario- and Platform-Aware Design (SPADe) flow for IBC systems (assuming it is a white box) [1] that:
  1. optimises control performance or quality-of-control (QoC),
  2. maximises effective resource utilisation and
  3. adheres to platform constraints (given allocation and fps).

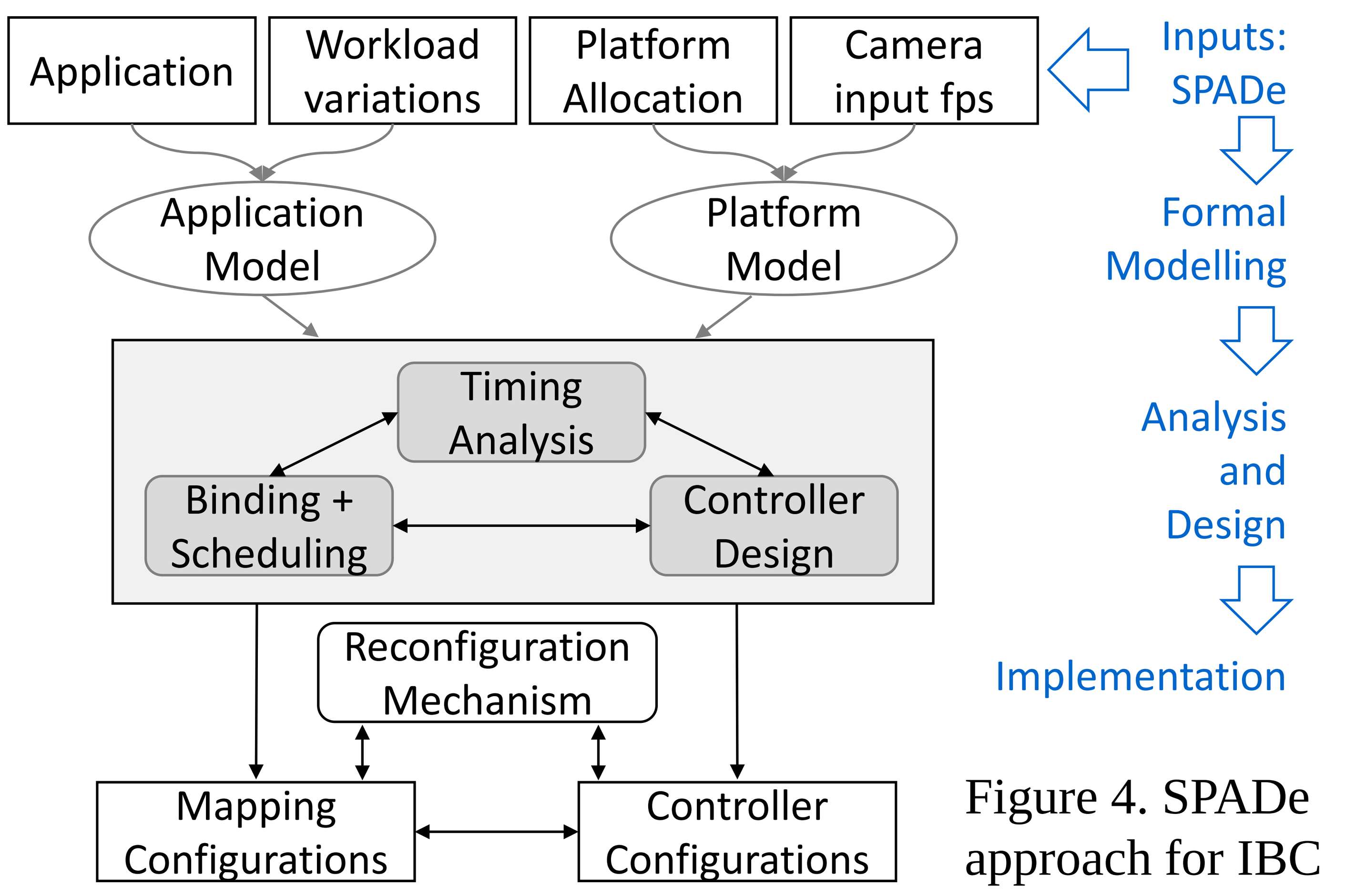

Figure 4. SPADe approach for IBC

- The SPADe approach involves the following aspects (see Fig. 4):
  a) Formal Modelling: i) identify and model the parameters that characterise workload variations, and ii) model application considering workload variations and platform considering platform constraints.
  b) Analysis and Design: Analyse application and platform models to design system configurations.
  c) Reconfiguration mechanism for run-time implementation.

Acknowledgement

This project has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation under grant agreement no 674875.

2. Controller Design vs Implementation

Control Design Engineer	Embedded Systems Engineer
The timing values for the worst-case (WC) workload are used for controller design [2].	Allocates sufficient platform resources to ensure the timing for the worst-case workload.
Sensing task is a black box	Controller design is a black box

The Gap
worst-case workload rarely occurs ⇨ inefficient resource utilisation

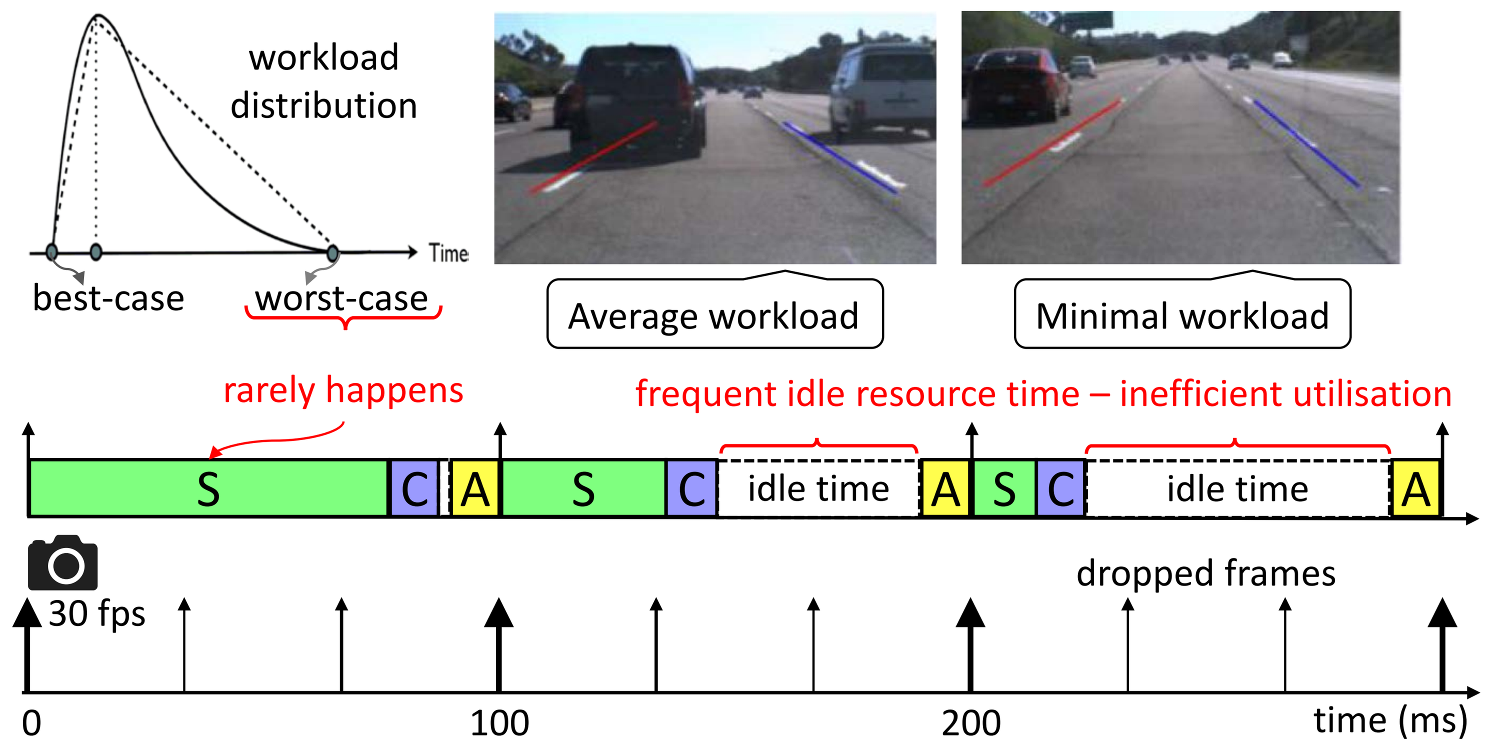

Figure 3. Design-Implementation Gap for worst-case (WC) workload.

- The execution time for sensing task depends on image workload variations that can be statistically analysed (e.g. as a PERT [3]).
- The designer can classify frequently occurring workload scenarios and always we observe that worst-case workload rarely occurs.
- An average workload scenario results in idling of the resource.
- A WC workload-based implementation means that frames have to be dropped even though the resource is idle/available.

5. Results & Conclusion

- SPADe maximises effective resouce utilisation and improves the settling time for the control system compared to WC design.

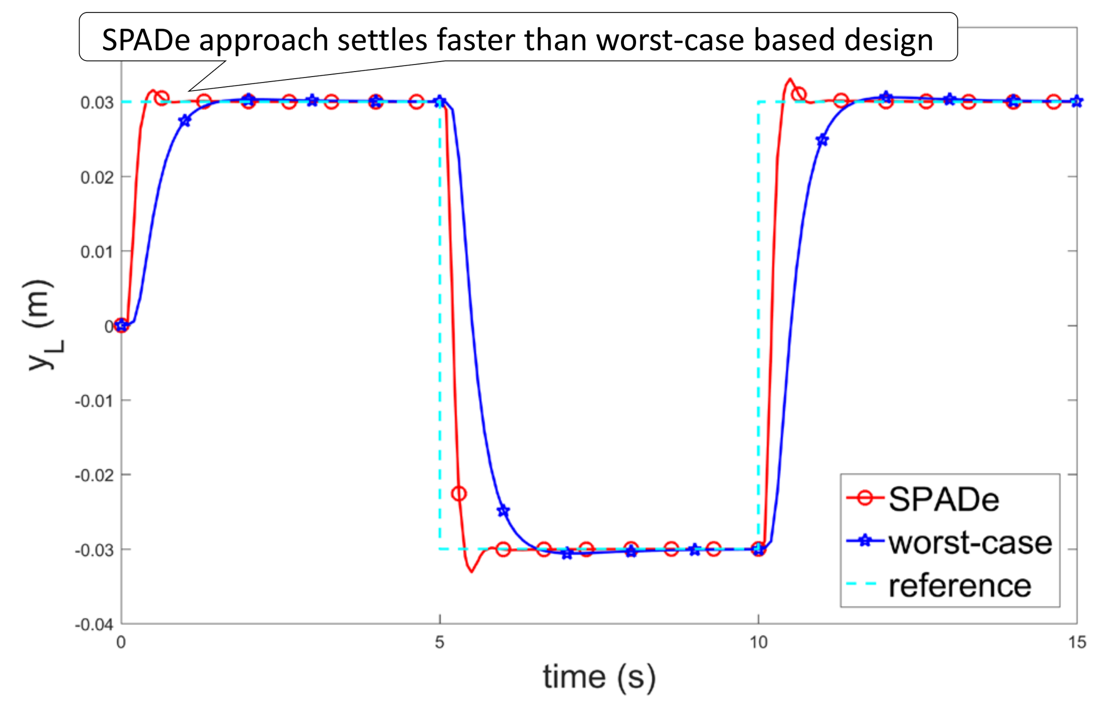

Figure 5. SPADe results: vision-based lateral control system [1]

- Considering workload variations is definitely beneficial for design.

6. Next Challenges

Extend SPADe approach for: i) (reconfigurable) pipelined controller design and implementation; ii) approximated image processing algorithms; and iii) communication-aware design for distributed IBC.

References

[1] S. Mohamed, D. Zhu, D. Goswami, & T. Basten, "Optimising Quality-of-Control for Data-intensive Multiprocessor Image-Based Control Systems considering Workload Variations." In 21st Euromicro Digital System Design Conference (DSD), 2018.
[2] S. Saidi, S. Steinhorst, A. Hamann, D. Ziegenbein, & M. Wolf, "Future automotive systems design: research challenges & opportunities (Special Session)." In International Conference on Hardware/Software Codesign & System Synthesis, 2018.
[3] S. Adyanthaya, Z. Zhang, M. Geilen, J. Voeten, T. Basten, & R. Schiffelers, "Robustness analysis of multiprocessor schedules," In SAMOS XIV, pages 9-17, 2014.