Synthesis of Signalling Strategies in Distributed Networks

Internship Description

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Context

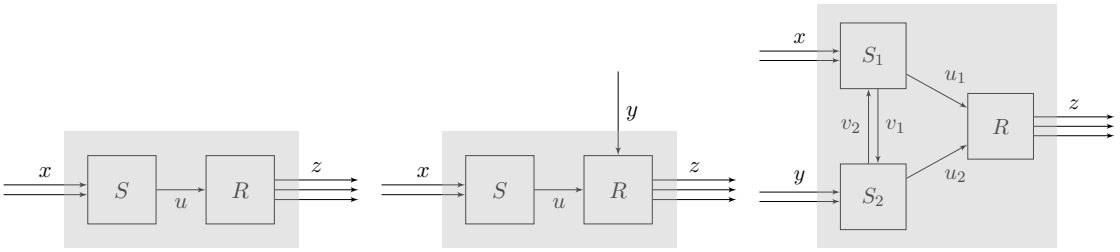
One challenge in modern computing is to design the components of a system so that they work well when put together. In general, when control actions are distributed between two or more components, the problem cannot be solved algorithmically. However, the purpose of distributed components is not only to perform control actions, but also to convey information via signalling actions. In this internship, we explore the distributed synthesis problem with a focus on signalling strategies.

Problem Setting

The simplest setup involves two processes: one, called Sender, that reads an input stream, and another one, called Receiver, that should output a stream of control actions related to the input in a specified ways. To do so, Sender can transmit a message stream to the Receiver via an internal channel. However, the internal channel is typically too narrow to hold the input verbosly. Thus, one needs to devise a signalling strategy with two components: a function for the Sender to encode the input into a message that fits into the internal channel, and a function for the Receiver to decode the message to produce a correct output.

We consider the problem of designing such signalling strategies for a synchronous system model where processes are implemented by finite-state machines.

In this basic setup, illustrated in Figure 1a, the problem is an instance of the distributed synthesis problem for pipelines, known to be effectively solvable. The problem becomes challenging when the Receiver additionally gets private input (Figure 1b) or, more generally, when the input is distributed among multiple senders that may communicate over channels of constrained bandwidth among each other and with the —still unique— output process (Figure 1c).



(a) Only Sender gets input from the environment

(b) Receiver has extra, private input

(c) Input distributed between two senders that may communicate

Figure 1: Sender-receiver architectures of increasing complexity. Multiple parallel edges illustrate larger bandwidth

Internship Goals

In the project, we will investigate the synthesis problem for signalling strategies in basic architectures as illustrated in Figure 1, with the aim of understanding for which cases the problem is effectively solvable.

The intern will have the occasion to become familiar with fundamental methods for automated synthesis, in particular, with techniques from the theory of automata on infinite objects and of games with imperfect information.

References

[1] Shaull Almagor, Denis Kuperberg, and Orna Kupferman. Regular sensing. In *34th International Conference on Foundation of Software Technology and Theoretical Computer Science, FSTTCS 2014*, volume 29 of *LIPIcs*, pages 161–173. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2014.

[2] D. Berwanger and L. Doyen. Observation and distinction. Representing information in infinite games. *Theory of Computing Systems*, 67(1):4–27, 2023.

[3] Patricia Bouyer. Games on graphs with a public signal monitoring. In *Foundations of Software Science and Computation Structures - 21st International Conference, FOSSACS 2018, Proceedings*, volume 10803 of *LNCS*, pages 530–547. Springer, 2018.

[4] P. Madhusudan and P. S. Thiagarajan. Distributed controller synthesis for local specifications. In *Automata, Languages and Programming, 28th International Colloquium, ICALP 2001, Proceedings*, volume 2076 of *LNCS*, pages 396–407. Springer, 2001.