Expressiveness for Distributed Systems

(Internship @ Data61, CSIRO, Sydney, Australia)

Background

To formally reason about distributed systems, different mechanisms such as networks of automata, Petri nets, process algebras or transition systems are used.

Certain systems, however, cannot be correctly specified and implemented without assuming some form of synchronous communication. A classic example is the Byzantine generals' problem, an agreement problem in which a group of generals, each commanding a portion of the Byzantine army, will only be successful when attacking at the same time. If only (unreliable) asynchronous communication is available, the generals cannot guarantee success of their attack.

Other systems, such as mutual exclusion protocols, cannot be expressed in default specification formalisms without making fairness assumptions that may be too strong for the intended applications.

This project aims at formalising these types of issues in a concise way and pinpointing where exactly the problem lays. This also involves finding the simplest possible formalisms that are strong enough for the task at hand.

Research Question and Tasks

The project will look at some particular specification formalisms (e.g. process algebras, Petri nets, or Turing machines) and try to analyse their expressiveness. It could involve one or more of the following tasks.

Formalising inexpressiveness results This involves the development of systems that cannot be implemented in a mechanism under consideration, as well as formal proofs of this.

Semantic foundation for expressiveness results In deciding whether a given system can be implemented using only asynchronous communication (or without making fairness assumptions), one needs to choose a semantic equivalence that specifies which aspects of the specified behaviour need to be preserved under implementation. The search for a suitable notion of equivalence could be a suitable topic.

Encoding one formalism into another To show that one formalism is at least as expressive as another one, a formal translation of the latter into the former could be provided; it needs to be shown that this translation satisfies the required correctness properties.

Non-interrupting reading Peterson's mutual exclusion protocol cannot be specified in standard process algebras like CCS; last year's project yielded an extension of CCS with non-blocking reading, which is expressive enough for this [see reference below]. Labelled transition systems modulo strong bisimilarity (the standard model of process algebras) are not suitable to formally compare the expressiveness of the old CCS and its extension, as strongly bisimilar systems need to be distinguished. One task could be the formulation of a new model of concurrency, extending labelled transition systems with extra information, which is appropriate for this task. A related task is finding an alternative notion of bisimilarity.

The concrete topic is set according to the applicant's interests and strengths.

References

An example of an impossibility result for asynchronous communication:

https://en.wikipedia.org/wiki/Two_Generals'_Problem

Our own work on extending CCS so as to capture mutual exclusion:

http://dx.doi.org/10.4204/EPTCS.255.2

Our work on expressiveness and asynchronous communication:

http://ts.data61.csiro.au/projects/concurrency/distributability.pml

General Information

Data61 is Australia's leading digital research powerhouse, offering the research capabilities, IP and collaboration programs to unleash the country's digital and data-driven potential, with a global context. By driving collaboration across industry, academia, government and the startup space, Data61 is able to help existing industries transform, and act as a catalyst in the creation of new technology-based industries.

The intern will be part of *Concurrency and Protocol Verification* (http://ts.data61.csiro.au/projects/concurrency/home.pml), a highly motivated group with different backgrounds (e.g., formal methods and network engineers), working at different institutes (Data61, UNSW, UQ, and Macquarie University). The successful applicant will work together with Prof. Rob van Glabbeek and Dr. Peter Höfner.

Sydney is the largest and most populous city in Australia. It is located on Australia's south-east coast of the Tasman Sea. With an approximate population of 5 million in the Sydney metropolitan area the city is the largest in Oceania. Sydney also ranks among the top 10 most liveable cities in the world according to Mercer Human Resource Consulting and The Economist.

Contact Information

If you have any questions concerning the internship, please do not hesitate to contact Rob van Glabbeek.