What purpose is served by a concept of process?

Robin Milner, November 2009

This note continues my first response "What is a process?" to the paper *Branching and Linear Time: Semantical Perspective* by Nain and Vardi.

I'm not surprised that there exist many different concepts of "process", as an equivalence class of agents or systems. Bearing in mind all the aspects of an informatic system – causality, non-determinism, probability, interaction, termination and more – the surprise would be if there were only a few interesting such equivalence relations.

In these remarks I want to distinguish the demands of two different kinds of system: (1) programs and their specifications, and (2) systems that occur naturally or semi-naturally. By the latter I mean systems whose parts (e.g. programs) may be designed by us but whose assembly may not be. The second kind subsumes the first.

A program enjoys an initial state, and may terminate. By contrast, in a naturally-occurring system it isn't always clear when it started and when it will finish; both events – if they occur at all – may be buried in the mists of time (past and future). Furthermore in such a system non-determinism is a fact, not under our control.

Although they do not say so, Nain and Vardi appear to limit their concern to programs and specifications. I believe Hoare also takes this as the main concern for CSP. My concern has increasingly been to emphasize the modelling of (semi-)natural systems, among which programs and specifications form a well-delineated subclass that is amenable to different abstractions, such as famously the failures preorder of CSP.

So I respect the goal of Nain and Vardi to model this subclass with a new formal notion of process, whose purpose is to ease verification. Equally, I insist that the notion of process as a bisimilarity equivalence class of systems[1] is especially appropriate for all systems, since bisimilarity rests firmly on the principle I attributed to Petri in my previous note that "information enters a non-deterministic system in finite quantities throughout time". Many other equivalence relations of systems are larger than bisimilarity, so can also be considered as equivalences of *processes*. The larger such an equivalence, the looser will be its representation of non-determinism.

In this note I haven't attempted to discuss the interesting new process notion of Nain and Vardi. The authors must not take this neglect as criticism. Instead I have only tried to combat what I consider to be some misunderstanding of the role played by weak bisimilarity. To be specific, here are a few pieces of their text that I ask them to reconsider; this may also have an implication for other parts.

- **Principle of Contextual Equivalence**: *Two processes are equivalent if they behave the same in all contexts.*

  Of course I accept this, but its meaning depends crucially on what it means for two processes to "behave the same". For the authors, it means that their difference cannot be "observed", i.e. cannot be detected by composition with a testing process which at some point shouts *yes* or *no*. But consider: any such test is done on the process in its start state. A program does have a well-defined start state,

[1] In my last note I talked of equivalence classes of *agents* or *systems* rather than of *processes*, because I wish to consider a process itself to be an equivalence class of systems.

but in general a (semi-)naturally occurring system does not: see above. So the tests for establishing equivalence of two such systems may have to be done on *any* of their states. This brings us much closer to bisimilarity.

- *[..] the term 'observation equivalence' for bisimulation-based equivalence [..] is perhaps unfortunate, as weak-bisimulation equivalence is in essence a notion of structural similarity.*

  The term *structural* is vague (see next item). In CCS, I defined an observation to be an interaction on an externally visible channel, and since weak bisimilarity is to do with the pattern of such interactions it was reasonable to use the term 'observation equivalence'. What is unfortunate is that now 'observation' has come to mean other things too! In my 1989 book I also called these observations *experiments*.

- *The most explicit advocacy of using bisimulation-based equivalence [..] argues in favour of using equivalence concepts that are based on internal structure [..]. [E]xpecting an implementation to have the same internal structure as a specification is highly unrealistic and impractical, as it requires the implementation to be too close to the specification.*

  This assertion is vague as to what is meant by "same internal structure". If it refers to the number, nature and connectivity among component agents interacting with one another, then it is simply false; my 1989 book shows this for a simple classroom example in Sections 1.3, 1.4 and 5.6. Instead, the structure respected by bisimulation involves only the two transition relations, and reflects the elegant principle attributed (above) to Petri.

  However, the value of bisimilarity is not for the *specification*, but much more for the *modelling* of systems. I already said in my 1980 book that further predicates of behaviour (e.g. for specification) needed to be found.

I look forward to any further debate on these points.