# How to Brew Your Own Hybrid/Cyberphysical Formalism

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The enthusiasm for hybrid and cyberphysical systems is exploding in today's world of cheap processors, sensors and controllers, and leads to the cost-effectiveness of a smart-everywhere approach to new services and systems. The presence of control as first class citizen in these systems leads to the impingement of discrete techniques from the computing sphere with continuous techniques from the physical systems sphere. It is often claimed that completely new formalisms will be needed to reason about these systems, a view that is a little puzzling considering that every component of such systems comes with a well understood mathematical model that captures the predictability of its behaviour in engineering contexts.

These days, most design and development of cyberphysical systems is very focused on the integration of and cooperation between existing tools and techniques from different areas of computer science and different branches of engineering and technology. Overwhelmingly, such tools and techniques are focused on discrete descriptions of system behaviour, and usually pay scant regard to the continuous aspects of physical behaviour. Unsurprisingly, such approaches are fraught with problems of compatibility and unpredictable interworking, arising from the lack of precision with which they view issues which are fundamentally continuous, and about which they consequently either cannot speak at all, or can say very little. All of which is evidently undesirable.

The way to master the incompatibility of the various existing techniques is not to oversee a war between their incompatible features, but to design a framework in which all of these features can be faithfully embedded, allowing their interrelationships to be properly expressed. Such a job has to be done bottom-up. In addressing it, equal weight should be given to input from computing formalisms, physical modelling approaches, and the various branches of mathematics that underpin these disciplines. When this is done conscientiously, starting from a basis that treats each of these aspects with an equal level of rigour, the remaining room for manoeuvre is surprisingly limited.

We survey this 'requirements-led' approach to designing a foundational framework for hybrid and cyberphysical systems, and the consequences that ensue. Recurring guides in this process are the way that discrete event formalisms relate to real world behaviour, and the deep analogies that exist between discrete event transitions on the one hand, and descriptions of continuous behaviour on the other. Further considerations affect notions of refinement for such formalisms. Existing formalisms for modelling features of cyberphysical systems emerge as partial projections of the fuller picture we develop. We discuss the prospects for automated and interactive verification within our framework, especially when supported by calculational oracles like Mathematica.