Hard-to-Define Events (HTDE) Workshop and their Contribution to Scientific Inquiry

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Abstract

In this report, I will discuss the proceedings, purpose, and implications of the Hard-to-Define Events (HTDE) 2012 workshop. This report will introduce readers to the events of the workshop itself, defining the role of HTDEs in scientific inquiry, and the broader implications of dealing with HTDEs in computational science. A major aim of HTDE 2012 was to explore how such "loose ends" of the scientific process are encountered and addressed in a variety of scientific fields. Presenters introduced workshop participants to HTDEs and approaches to dealing with HTDEs in four distinct areas of scientific inquiry. These include: the artificial evolution of cognition, the fluid dynamics of animal behavior, high-performance scientific computing, and the modeling of physiology and behavior. Short interviews were summarized in PowerPoint and provided to workshop participants as supplemental web content. These interviews provided additional examples of HTDEs from the subdisciplines of human genetics and developmental biology. The broader implications of HTDE investigations are discussed in the second part of this report. This includes examples of how the lessons of HTDE 2012 might be used in constructing more effective artificial life representations and simulations.

Introduction

This report will provide readers with a review and discussion of the Hard-to-Define Events (HTDE) 2012 workshop. The topic will be introduced and discussed in three ways: describing the proceedings of the workshop itself, defining the role of HTDEs in the broader context of scientific inquiry, and the broader implications of dealing with HTDEs in a single field of inquiry. The role of rare events, high degrees of complexity, and puzzling results in the scientific process is an issue that has been dealt with in a host of different ways across the scientific community. Therefore, examples from the multitude of scientific disciplines featured at HTDE 2012 will be used to understand why this is both a timely and poorly characterized approach to scientific inquiry. Yet it is the ability to identify and potentially deal with HTDEs in computational science which offers the most promise for future directions.

The HTDE 2012 Workshop (Figure 1) was hosted at Artificial Life (ALife) XIII, which took place during July 2012 in East Lansing, MI. The impetus for this workshop was to bring attention to rare events, puzzling results, and emerging computational techniques amongst members of the scientific and artificial life community. A workshop was held on HTDEs to provide an interesting discussion of these issues amongst people of different scientific

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backgrounds (see Figure 1). The topic of HTDEs was particularly relevant to the conference theme of Evolution in Action in that evolution often produces outcomes which are counter-intuitive and hard to understand using conventional approaches. HTDE was scheduled as a two-hour block during the workshop period of the Alife XIII conference. This included an introductory lecture (Figure 2, left) by Bradly Alicea, in addition to topical presentations by Laura Grabowski, Bill Punch, Nicholas Keeney, and Bradly Alicea. Attendance ranged from 15-25 people, as there was interchange of attendees with the parallel sessions. Interviews were also conducted with Anne Buchanan (Anthropology) and Michael Levin (Computer Science) on the presence of such phenomena in biological systems (human genetic and developmental, respectively).

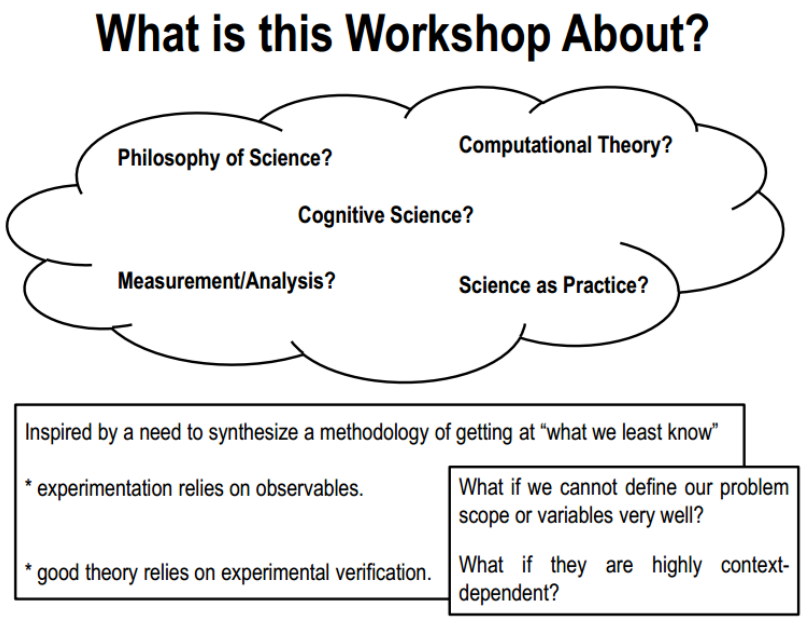

Figure 1. The various interdisciplinary strands (in graphical form) that contribute to the HTDE perspective.

Even though the presenters were from disparate areas of science, the presentations tended to cover complementary issues. Laura Grabowski (Figure 2, right) discussed her work on evolving spatial navigation abilities in digital organisms called Avidians. With slight modifications to the Avida [1] digital evolution platform, she was able to experimentally demonstrate the evolution of path integration [2]. Nicholas Keeney, an Earth Science graduate student, combined fluid dynamics modeling with behavioral studies to look at the phenomenon of "drunk fish". As a representative of iCER (Institute for Cyber-Enabled Research), Bill Punch gave a presentation on the world of parallel and high-performance computing. Bradly Alicea rounded out the session with a discussion of how phenomenological models of complex neural processes at multiple scales of organization can be used to characterize a hard-to-define event. While the topics represented by the HTDE 2012 lineup was particular to the host conference (Alife XIII), the HTDE approach is applicable to any discipline which features poorly-characterized phenomenology, ill-posed problems, or complex multivariate outcomes. Indeed, the examples featured at HTDE 2012 cover Cognition, Evolution, Ecology, Computer Science, and Physiology.

The short interviews revealed specific findings which demonstrate the challenges posed by HTDEs. The idea behind picking people's brains for their research curiosities might seem to be an odd approach, but actually serves as an instructional tool. The curiosities featured in these interviews [3] demonstrate both what is unsettled and usually not discussed in the course of a particular scientific investigation. Whereas the average scientific report tells us what was ultimately successful (e.g. statistically significant results), another major component of scientific discovery depends on mediating between the positive result and what is either unclear or unknown. This provides new perspectives on the scientific process for professional scientists, students, and the general public. Lecture slides and videos from the HTDE workshop were archived at *Synthetic Daisies* blog [4]. This workshop archive also features updates, mainly in the form of blog posts, articles, and presentations which keeps the spirit of the workshop alive. In this sense, anyone who is so inclined can learn about scientific inconsistencies and conceptual puzzles that characterize the HTDE approach.

Figure 2. A few scenes from the workshop videos. **LEFT:** A presenter (Bradly Alicea) giving an introduction to the workshop's structure and the HTDE approach. **RIGHT:** A presenter (Laura Grabowski) giving a presentation on the evolution of intelligence in Avida.

Broader Themes of the Workshop

As the HTDE approach has the potential to be useful beyond the confines of the workshop itself, there are several broader themes that are worth exploring further. The HTDE workshop was initiated by a *Synthetic Daisies* blog post from January, 2012 [5]. This blog post focused on the analysis, simulation, and representation of rare events (e.g. strong earthquakes, genetic mutants). Rare events serve as a potential benchmark for the HTDE approach, as rare events are events or objects that range from simple deviation from a normal distribution to extreme 1/f noise. Such events are not only rare occurrences but also recurrent phenomena that cannot be easily observed and characterized using conventional models. In the case of more conventional adaptive computing paradigms, the HTDE approach can be applied to overcoming catastrophic failures and exception handling capabilities. This is particularly true for real-time models of social or biological systems with highly-complex dynamics and difficult to measure properties.

At HTDE 2012, both the introductory lecture (Figure 3) and Bill Punch's lecture (Figure 4) spoke to the notion that modern biological and social sciences lack the conceptual tools to deal with the reality of incomplete problem formulation and difficult to observe phenomena. So-called "wicked problems" [6] exemplify this difficulty. From a practical standpoint, this complexity can be tamed somewhat through the application of large-scale, parallel computing. A future need for dealing with HTDEs is a computational infrastructure that includes both algorithmic and analytical innovation.

Figure 3. Welcome to the HTDE Workshop (Bradly Alicea). Length, 19:15. Vimeo Link.

Bradly Alicea's talk on brain science (Figure 5) focuses on the difficulty of finding robust heuristic solutions to scientific problems, and demonstrates this for the domain of phenomenological modeling. Model abstractions can be shown to exhibit inherent incompleteness, particularly in the case of vertical organization of biological systems related to the study of brain and behavior. Yet models can also allow for important new functions and potential avenues of causality to be proposed. While phenomenological models can be used in tandem with empirical investigation, it is the models themselves that are critical for gaining a deeper perspective on data. This is a missing piece of big data investigations [7], and is perhaps one reason why big data analysis sometimes yields odd results.

The empirical work of Laura Grabowski (Figure 6) and Nicholas Keeney (Figure 7), show that exceptions to the theoretical rule has its roots in the incomplete nature of empirical investigations. In Laura's model system, it was assumed that a computational model of behavior could yield a wider range of behaviors than could be seen in nature. Indeed, the use of generative models provides us with opportunities to observe phenomena that upend theoretical assumptions. In Nicholas' model system, an empirical curiosity appears to have novel information that can likewise upend theoretical assumptions. These types of "disruptive" observations [8] serve to counter the information provided by phenomenological models.

Figure 4. Parallel Processing and Why it Matters to Everyone (Bill Punch). Length, 23:11. Vimeo Link.

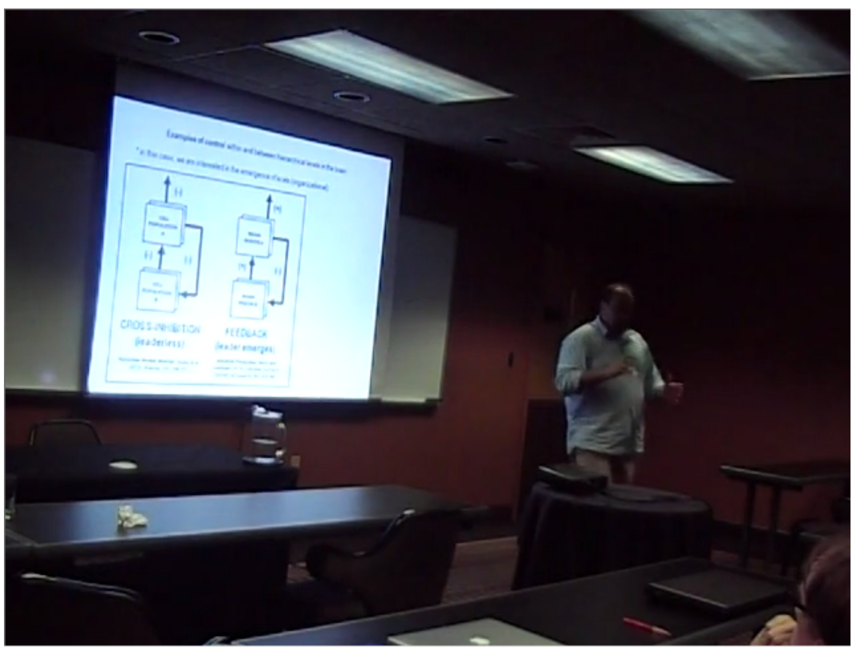

Figure 5. Multiscale and Rare Events in Physiology (Bradly Alicea). Length, 19:26. Vimeo link

One domain in which the HTDE approach might serve as a practical advance is in the case of rule-based or hypothesis-driven exploration of uncharacterized or unknowable domains. Yet another place where the HTDE approach might perform well is in the world of natural computing [9]. Natural computing deals with domains that, even when they are well-characterized, are not easily decomposed using classical data structures. With respect to the world of empiricism and models, natural computing has all of the features of an HTDE phenomenon. We could take this a step further and develop new data structures and computational logics based on what has been learned from applying the HTDE approach to understanding scientific inquiry.

Figure 6. Toward Robotic Intelligence: Evolution of Memory Use in Digital Organisms (Laura Grabowski). Length, 28:10. Vimeo link.

Future Directions

While the workshop itself has come and gone, the challenges posed by HTDEs have not. The challenge of such phenomena is three-fold. First, hard-to-define problems resemble inverse and ill-posed problems in that simple solutions are either difficult or impossible to obtain. Secondly, hard-to-define events themselves are not easily amenable to computation. This covers systems which are dominated by the presence of rare events, computational complexity, and transient equilibria. Yet the HTDE approach also makes an explicit link to computational abstraction and computability. From a big-picture perspective, HTDE constitute theoretical exceptions to the rule. This includes new ways to characterize problems, particularly those which upend the current theoretical *status quo*.

In terms of studying HTDEs further, it is important to realize that the HTDE approach goes well beyond the traditional tension between abstraction and realism found in fields as diverse as cognition, quantum physics, and mathematics. At its most implicit level, HTDE deals with our inability to fully characterize the chaotic behaviors inherent in the natural world. As computation moves from a strictly *in silico* environment to a host of physical and natural settings, the HTDE approach is quickly gaining relevance. Quite obviously then, one potential direction involves applying the HTDE idea to computer science in a more explicit fashion. As a computer science approach, HTDE could serve as a new way to deal with exception handling in real-time systems and applications that are “out in the world”. Whereas the HTDE approach is a means of representing and conceptualizing unexpected and counter-intuitive outcomes, the HTDE approach would also require slightly different benchmarking practices. That is, rather than benchmarking on well-known, canonical problems, the HTDE approach would involve benchmarking on problems of high conceptual and practical complexity. It is in this way that the HTDE approach returns to its roots in empirical, naturalistic investigation. As a test-bed of empirical principles, the physical world offers many examples of rare events, multi-scale complexity, and hard-to-encapsulate problem spaces that require a unified set of methodologies. From a practical standpoint, however, the HTDE approach would require that all computational models be generative. While Artificial Life perspectives may not be able to help us establish a formal HTDE computing paradigm, they will allow for us to open new conceptual vistas.

Figure 7. Drawing Conclusions from Drunk Fish in Dynamic Environments (Nicholas Keeney). Length, 20:30. Vimeo link.

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