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A Scientific Realist Perspective for Computer Science Inquiry

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Introduction and Motivation

The conduct of any scientific discipline should be guided "by a research perspective or paradigm, comprising ontological, epistemological and methodological assumptions that together frames the nature of the research and the role of the researcher in the scientific inquiry" (Khazanchi and Munkvold, 2002, p. 1). However, computer science research has been lacking in its ability to discuss and generate these perspectives. In particular, we have identified the following six challenges facing computer science research today.

1. Identity crisis (McKee, 1995; Brooks, 1996; Denning, 2005; Tichy, 1998; Wegner, 1976; Denning, 2005; Eden, 2007);
2. Lack of philosophical underpinnings (Lukowicz et al., 1994; Rapaport, 2005; Tedre, 2007);
3. Lack of emphasis in methodology (Vessey, 2002; Holz, 2006; Randolph, 2007; Ramesh et al., 2004; Tichy, 1998);
4. Lack of training in philosophical foundations of scientific research (Glass, 1995; Mudge, 1996; Holz, 2006; Tedre, 2007);
5. Imbalance between applied and theoretical research (Aho et al., 1997; Mertens 1998); and
6. Computer Science research needs to contribute to the large body of knowledge and engender higher order thinking in the larger information technology (IT) domain (Colburn, 2000; Wing, 2008).

In view of the above challenges, in this article we argue for the importance of defining the philosophical and methodological assumptions underlying computer science research using a scientific realist orientation. The scientific realist perspective and philosophy of science principles can address some of the challenges facing the computer science discipline. This perspective can allow CS researchers to assess alternative or complementary methodological options available to them and provide them guidance on how to make...
decisions about the choices they face. A philosophical orientation can also provide guidance for the computer science researchers in their research conduction efforts in general by providing an understanding what research is scientific and valid, and what research is valuable contribution to knowledge. In addition, philosophical thinking allows for a deeper understanding of research phenomenon, which is important in contributing to the larger body of knowledge in IT. We argue that scientific realism is the most suitable philosophy for computer scientists.

Scientific Realism in Computer Science

Scientific realists believe that the entities postulated by scientific theories (observable, unobservable, tangible, intangible) are real entities in the world, with approximately the properties attributed to them by the best available scientific theories (Boyd, 1984). For example, in natural science, these entities could be things such as quarks, genes, and superfluids, in social science there are unobservable entities, such as classes and systems of norms, whereas in computer science there are entities such as algorithms, processes, data structures. From the scientific realist perspective, historical analysis reveals clear progress in the demonstration of improved theoretical representations of physical and social phenomena (Boyd, 1984). Consistent with this view, each scientific discovery leads to a closer approximation of reality. Hypotheses derived from theory are used to direct the scientific agenda, but such constructs do not determine the outcome of scientific endeavor. Hunt (1994) argues for scientific realism as a philosophy for building and testing theory. Scientific realism emerged from a tradition of thought in empiricist philosophy of science; however it rejects many early positivist assumptions (Leplin, 1984).

To understand the role of scientific realism in computer science, we analyze a number of research exemplars in the computer science field. It is understood and generally accepted that a researcher's understanding is based on values, culture, training and experiences that he/she brings to the research situation and that this might be different from those of the participants in the situation. The philosophical framework adopted by researchers can be identified in terms of the assumptions they make about the nature of the reality being studied, knowledge claims about what we can and cannot know, and the ways in which they utilize theories and findings. There are many computer science researchers who are probably scientific realists implicitly, as demonstrated by their published work. In our evaluation, we have identified many examples of research problems that reflect essential characteristics of the scientific realism paradigm. We illustrate this result by
describing the research problem and considering the attributes of scientific realism that are implicitly represented in the study of the problem with appropriate evidentiary support provided from published sources. In the Table below we illustrate two examples of computing research problems that reflect essential characteristics of the scientific realism paradigm. The first column of the table states the name of the problem, the second column provides the description of the problem, the third column discusses how scientific realism was implicitly used in the problem, and the fourth column contains the sources that were used in our analysis.

Table 1. Computer Science research problems with characteristics of the scientific realism paradigm

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<tr>
<th>Problem</th>
<th>Description</th>
<th>Discussion</th>
<th>Sources</th>
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<td>Artificial Neural Networks (ANNs)</td>
<td>ANN is a mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. It is an adaptive, mostly nonlinear system that is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. Some of the advantages of the ANN are the ability to learn, ease of implementation, and ability to adapt and self-configure.</td>
<td>Although artificial neurons attempt to model the human neurons, ANN deals with unobservable entities, artificial neurons. Many explorative experiments have been conducted in ANN area and they revealed properties better than those theoretically predicted. This resulted in developing better theories for ANN. This falls into the falsifiability characteristic of scientific realism. This example shows how scientific theories can get better, i.e. are able to answer more and more questions.</td>
<td>Gurney, 1997; Leplin, 1984; Tichy, 1998; Yegnanarayana, 1999.</td>
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<td>Big-step and Small-step Semantics</td>
<td>Small-step semantics specifies the operation of a program one step at a time. An alternative to small-step operational semantics is a big-step operational semantics, where the entire transition from a configuration (an expression, state) pair to a final value is specified. Small-step semantics can model more complex features, like programs that run forever and concurrency, while big-step semantics more closely models an actual recursive interpreter.</td>
<td>Davvy and Milliken proved the equivalence of the small-step form and big-step form semantics, two standard styles of specification of abstract machines. This proof illustrates how two different methods can be used to obtain the same meaning of the program. This is an example of obtaining the same result through two different methods. According to scientific realism the fact that these different methods lead to the same description of the meaning of a program means that the meaning of the program obtained is in fact valid and is a closer approximation to a true model.</td>
<td>Davvy and Milliken, 2007; Huat, 1990; McMullin, 1984; Schmidt, 2003.</td>
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Based on these and other examples, we support our contention that the scientific realism paradigm provides a useful grounding for computer science researchers (and research) by elevating the importance of philosophical issues and thus allowing for a more consistent and informed approach to research.

**Discussion and Conclusion**

We argue that scientific realism is well suited for computer science research. We believe that with a deeper understanding and appreciation of the philosophy of computer science, specifically a scientific realist perspective, computing researchers can contribute to a deeper understanding of the nature of computer science and the broader IT domain. Scientific realism is appropriate for computer science because it does not make the observable-unobservable (tangible-intangible) distinction among entities studied in a research, it allows for co-existence of both quantitative and qualitative methods, it provides a good explanation of empirical success of science in general, and theory-ladenness of data based on observation is not problematic using scientific realism approach. Under this paradigm, computer science researchers can have more tools available to them by using various methods within theoretical and applied research. Finally, we also hope to stimulate discussion and encourage debate among computer scientists as to how they should proceed with conducting research and what research paradigm is the most appropriate to use in CS domain.
References


Additional references are available upon request from the authors.