

from the index, where a third of the nine chapters on theory are largely concerned with rules while model-based and qualitative reasoning, two of the mainstays of work on “deep knowledge”¹ are relegated to subsections of the chapter on “advanced techniques”. The problem is also clear from the fact that alternative methods of knowledge representation, such as frames, are treated rather briefly, and that the chapter on verification and validation only gives examples concerning rules. Thus it looks a lot as though *The Engineering of Knowledge-Based Systems* started life concentrating on rule-based systems and was expanded rather late in the day by the addition of a couple of chapters which gloss over additional topics. This is a shame because, with a little more effort to make the brief descriptions of areas such as objects and qualitative reasoning, the book could have been very good indeed.

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Recent advances in qualitative physics edited by Boi Faltings and Peter Struss, MIT Press, 1992, £35.95, pp 449, ISBN 0-262-06142-2.

Qualitative physics, for those who have not come across the subject before, is a subfield of artificial intelligence which attempts to model physical systems. The systems that are considered range in complexity from the sublimely simple, such as a mass oscillating at the end of a spring, to the ridiculously complex, such as the cooling plant of a pressurized water reactor. Thus the domain of the system provides the physics.² The qualitiveness comes from the approach used to analyse the systems. A classical analysis would be by the numerical simulation or analytic solution of a set of differential equations, with a simulation being necessary for more complex systems because typically such systems involve differential equations that are beyond analytical solution.³ Now to either perform a simulation of or obtain results from an analytic solution for a given system, it is necessary to have a good deal of precise numerical information about that system. Without such data, classical engineering techniques are useless. However, the lack of this kind of information does not stop trained engineers performing “back of an envelope” type calculations to assess the approximate behaviour of a system without going into numerical detail, obtaining results such as: “closing this valve will cause the flow-rate through that pipe to increase, and so the pressure in that third chamber will fall”. It is precisely this kind of qualitative, that is as opposed to quantitative, reasoning that qualitative physics tries to deliver.

Now, as with most books that include the words “recent advances” in their title, *Recent Advances in Qualitative Physics* is a collection of papers. According to the editors' foreword, it is a selection of the papers presented at the 1989 and 1990 International Workshop on Qualitative Physics, and as such might simply be dismissed as yet another collection of papers whose only connection is that they were presented at the same conference, and whose only merit is that they boost the authors' publications list since the same, or very similar, paper is already available in the proceedings of the meeting. Happily, neither of these criticisms can be applied to this volume.

To begin with, most of the papers have not appeared elsewhere, or at least had not at the time that the collection was put together. This is largely because the proceedings of the workshop are not published, the organizers preferring to keep the meeting small and exclusive (participation is by invitation only), and thus productive for the participants rather than large and open and thus less likely to induce interaction between attendees. Since the potential audience for new work on

¹That is, knowledge which encodes information about the structure of the domain as opposed to the shallow knowledge of rule-based systems which only deals with how to solve the problem at hand.

²Of course, as with all sweeping generalizations there are many, varied, exceptions from systems that reason about the human body to those that consider the propagation of uncertain information in probabilistic networks.

³For those unversed in the arcane mysteries of applied integral calculus it should be noted that analytical solutions may only be obtained for the very simplest differential equations—it is simply not known how to solve most of them.

qualitative physics far exceeds the audience at the workshop, there is a good argument for making those papers that would not otherwise be published more generally available. This argument is reinforced by the common theme running through many of the papers, a theme which can only be appreciated after a little more discussion of qualitative physics.

The way that the early papers on qualitative physics (Bobrow, 1984) got around the problem of having insufficient numerical information, was to do away with numbers altogether. Instead, qualitative systems deal with the *quantity space*, which is a series of landmark values against which the values of various important variables and their derivatives can be compared. The set of landmarks is typically small, and in early work was the set $\{-\infty, 0, \infty\}$, allowing values to be distinguished only as positive, negative and zero. Despite the severity of the abstraction, this initial work proved very promising, and prompted people to start considering much more complex systems like the nuclear plant mentioned above, or the power generator of a naval vessel. Under these more exacting conditions, a basic flaw was discovered—qualitative methods have a tendency to over-abstract giving vacuous results. As an example, consider determining the difference of two positive quantities A and B . If the relative magnitude of the two is not known, as is the case with the basic quantity space, we cannot say whether the value $A - B$ is positive, negative or zero so it is written as ? (which is self-explanatory). The occurrence of ? causes problems, both computationally if one wants to try to establish what happens if the ? really represents a positive value and how this differs from what happens if it is zero, or in terms of the usefulness of the results since finding out that a value is ? is totally uninformative. It is the resolution of this problem which is the common theme of the papers in *Recent Advances in Qualitative Physics*.

It turns out that there are a number of different ways of tackling the kind of over-abstraction that is a feature of early qualitative systems, and a number of these are covered by papers in the book. For instance, one of the most obvious solutions is to include more landmarks, allowing the values of variables to be determined more precisely. This may be achieved by allowing alternative sets of landmarks to be adopted when required, or by mixing whatever numerical information is available in with the basic qualitative information. Alternatively, it is possible to adopt fuzzy intervals so that variables may be assigned “linguistic” values like “big” and “small”, or to establish the bounds on the value of a particular variable rather than trying to pin it down exactly. Other solutions focus on reducing the complexity of models, since models that go into too much detail for a particular task tend to be a cause of uninformative answers. Complexity can be reduced by increasing abstraction, this time in the model rather than in the value of variables in the model, and several authors describe different abstraction mechanisms.

Because the theme of handling uninformative solutions is accidental, stemming from the fact that several people were facing the same problem at the same time, around half of the papers deal with other topics and these are somewhat diverse. There is a paper on the construction of qualitative models, and one on extending qualitative physics to cover kinematics (the study of motion without reference to mass or force), and there are papers on qualitative methods in design and the modelling of traffic flow. There are also several papers on computational aspects—an important topic given the intractability of much qualitative reasoning. One of the most interesting, in my opinion, gives a new and more efficient algorithm for temporal reasoning and another useful one considers resource-bound qualitative reasoning. These, though are just the ones that I found most useful, and I am sure that other readers would choose to highlight different contributions. I am also sure that anyone interested in qualitative reasoning, whether about physical systems or anything else, is likely to find something of interest in this collection, and so it seems to be a thoroughly worthwhile contribution to the field and a decent addition to any library.

References

Bobrow, D (Ed.), 1984. *Qualitative Reasoning about Physical Systems*. North-Holland.

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