Computation: A Tale of Two Notions

1. Introduction

What is computation? At the heart of this question appears to lie a paradox. On the one hand, computation looks like the kind of thing virtually any physical system does. After all, physics ensures that some states are followed by other states in a rule-like manner. This view has come to be known as ‘pancomputationailsm’. On the other hand, computation looks like the kind of thing that only emerged in recent human history. On this view, very few physical systems compute, namely those that were technologically designed to do so. We may call this ‘oligocomputationalism’. This talk aims to resolve the apparent paradox by putting forward two non-rivalling notions of computation: one that underwrites pancomputationalism and another that underwrites oligocomputationalism. It is argued that each notion is legitimate because it captures different uses of the term ‘computation’.

2. Manipulable and Non-Manipulable Computation

The account proposed below builds on the long tradition of viewing computation as involving maps and in particular relations between input and output states – e.g. Putnam (1988). More precisely, on this view, for a system to compute it is necessary that there is a set of input states and a set of output states and the two sets are related through what we can mathematically characterise as a mapping or function. The two notions to be discussed below incorporate this as one among other necessary conditions for computation.

Let us begin with non-manipulable computation. Suppose we build a digital computer with eight states whose sole job is to map states 1, 2, 3 and 4 to states 5, 6, 7 and 8 respectively. If we cannot alter the range of mappings, say from 2, 3, 4 and 1 to 5, 6, 7 and 8 respectively, without altering the physical basis of the system (in this case its hardware) then we may call the range of mappings ‘rigid'. Beyond this kind of rigidity there is also a rigidity associated with the range of input states. Thus, if, from the very start, the only input states are 1, 2, 3 and 4 then we have a rigid range. If, however, those input states are either replaced with others (say 9, 10, 11 and 12), expanded (say 1, 2, 3, 4 and 10) or contracted (1, 2 and 3), then the range of inputs is flexible. With these notions at hand, we are now ready to define non-manipulable computation:

> A physical system performs *non-manipulable computations* IFF at some level of organisation its transitions from one state to another can be faithfully and non-superfluously represented in terms of a rigid range of mappings and input states.

Now all digital computers are physical systems that perform non-manipulable computations at the hardware level. At that level, they are simply circuits consisting of electronic switches that operate as logic gates, taking certain voltages as inputs and returning certain voltages as outputs. The circuit of any given digital computer is fixed, thus the range of mappings is rigid. The range of inputs is also rigid as it effectively takes one of two forms: low or high voltage.

More controversially, several naturally-occurring systems also undergo transitions that satisfy the above definition. Take chunks of ice on a mountaintop in the spring. As the temperature rises, the ice melts. The system thus transitions from a state of low entropy to a state of high entropy precisely as the second law of thermodynamics dictates. There is thus a rigid range of mappings, viz. one mapping from a state of low entropy to a state of high entropy. Moreover, given the choice of system, the range of input states is also rigid: high vs. low entropy. Seeing as entropy-increase is a general rule, virtually all physical systems compute in this sense.

Pancomputationalism's opponents – e.g. Godfrey-Smith (2009) – would surely find this unacceptable. Recall, however, that this is only one of two notions of computation. When critics rail against pancomputationalism they do so because they have something else in mind when they utter the word 'computation'. To be exact, they think that computation is something man-made. As it turns out, we can define a narrower notion of computation that does more justice to this intuition.

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Consider digital computers again. Though at the lowest level such machines perform non-manipulable computations, at higher-levels they compute in the manipulable sense. At the level of operating systems, for example, a number of alternative range of mappings become available since different operating systems can be implemented on the same hardware. Ditto for the range of inputs. At the level of interface devices, for example, the range of inputs is unrestricted. Over the years, we have developed input devices like keyboards, mice, drives, light sensors, accelerometers and brainwave-reading caps. Crucially, the same flexibility cannot be witnessed in the case of systems like chunks of ice. In that case, and as has already been argued, the range of neither the mappings nor the inputs is flexible.

3. Comparison with Existing Views

In the final section, I compare the current view with two others: the mechanistic view of Piccinini (2015) and the abstract evolution view of Horsman et al. (2014). Despite some differences, all three views have some important elements in common, e.g. they allow some naturally-occurring systems to compute. I conclude the talk by addressing how my account solves some puzzles, e.g. how to do justice to the notion of miscomputation, that seem to plague other accounts of computation.

References:

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