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Computation harvesting from nature dynamics for predicting wind speed and direction

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Abstract

Natural phenomena generate complex dynamics because of nonlinear interactions among their components. The dynamics can be exploited as a kind of computational resource. For example, in the framework of natural computation, various natural phenomena such as quantum mechanics and cellular dynamics are used to realize general purpose calculations or logical operations. In recent years, simple collection of such nature dynamics has become possible in a sensor-rich society. For example, images of plant movement that have been captured indirectly by a surveillance camera can be regarded as sensor outputs reflecting the state of the wind striking the plant. Herein, based on ideas of physical reservoir computing, we present a methodology for wind speed and direction estimation from naturally occurring sensors in movies. Then we demonstrate its effectiveness through experimentation. Specifically using the proposed methodology, we investigate the computational capability of the nature dynamics, revealing its high robustness and generalization performance for computation.

Introduction

Conventional computing devices, ranging from digital computers to natural computing methods, are realized as a result of the precise design of natural phenomena in physical, chemical, and biological systems, as shown in Fig 1 and as explained hereinafter. The computational capabilities of such conventional computers are based on diverse physical quantities and dynamical phenomena inherent in nature. Specifically, recent publications include investigations pertaining to natural computations, with a particular emphasis on the utilization of physical media. This emphasis is particularly notable within the domains of biology and ecology [1–3]. However, such characteristics which are used as a basis of computation are not necessarily devised artificially: they are also available without design by human intervention. Those natural phenomena might be exploited as resources for computation if they could be extracted adequately without precise design. After discussing such unconventional natural computing with little human intervention from the perspective of computation

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harvesting from real-world phenomena, we validate the concept with demonstration by experimentation.

As described above, conventional computation with sophisticated algorithms such as machine learning is performed by physical phenomena inside computing devices, accompanied by elaborate design. In reality, physical phenomena in nature are capable of generating complex dynamics, but generally speaking, they cannot be used as they are for conventional computation as they are. Such non-designed natural dynamics if converted to computational processes could potentially support processes at low computational cost and with low energy expenditure. Specifically, natural phenomena involve complex interactions among their components and potentially generate rich patterns, which can be exploited to achieve some computing tasks and outcomes without the need for elaborate algorithms. Moreover, unintended computational capability can be acquired from nature. Based on these facts, computational processes can be extracted from natural phenomena: computation can be harvested.

First, the computation harvesting concept must be defined. If the target natural phenomena in the environment are not complicated, then one can model and simulate the phenomena mathematically using digital computers. However, generally speaking, most natural phenomena are so complex that they cannot be readily modeled. Accordingly, we assume that natural phenomena and their environment are regarded as a natural computer generating data and performance of the desired computation with the data. Practically speaking, the methods for extracting useful information obtained by sensing the real world and combining them for computation are crucially important. We designate the process of sensing dynamics in undesigned nature and the use of its information for computation as "computation harvesting". Fig 1 presents a schematic illustration of the computation harvesting concept compared with conventional computing. Conventional computing systems are designed to be used with input devices to the computing units and to be used with read out sensors on the units. By contrast,

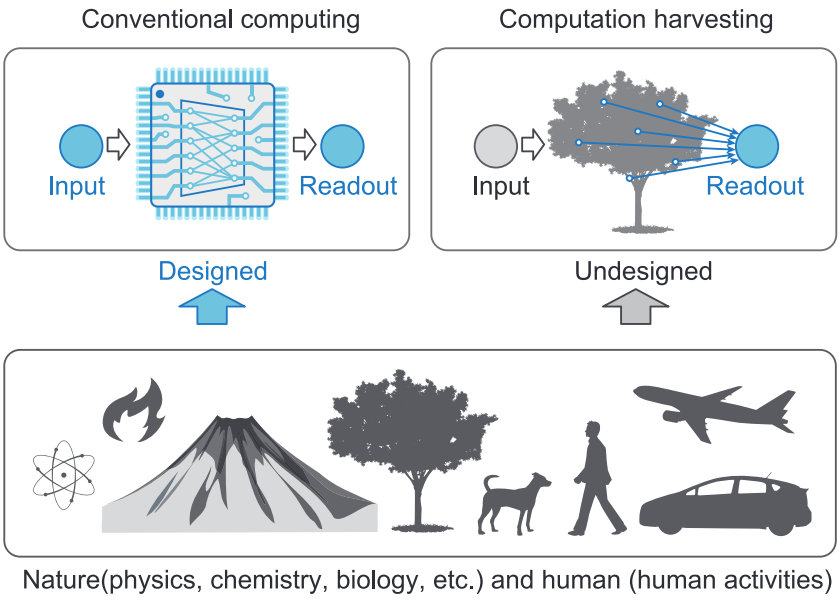

Fig 1. Computation harvesting. Schematic illustration of computation harvesting with reservoir computing (right) compared to the conventional one (left). The physical reservoir in the proposed method is not necessarily designed physically.

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