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The Development of Artificial Life and Its Relationship with Artificial Intelligence

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Artificial life (also known as AL) is an interdisciplinary study of life-like processes that applies the synthetic methodology instead of analysis methodology to observe the living process of living systems in the artificial environment and make the essential property of emergent behaviors clear. Meanwhile, artificial life is also a field of living system research which is jointly associated with biology, life science, computer science, and philosophy. In addition, the nature of artificial life is not only established on the study of "life-as-we-know-it", but also that of "life-as-it-might-be". In that, the fundamental property of natural living systems can be effectively discovered by the comprehensive process based on "life-as-it-might-be". Moreover, the study of artificial life cannot only bring the contribution to explain the living behaviours and explore the origin of life, but it also provides a new approach to biological research.

Keywords: Artificial Life

Introduction

"Artificial life (also known as AL, A-Life, or Alife) is an interdisciplinary study of life-like processes using a synthetic methodology"[1], and it is also a field of living system research jointly associated with biology, life science, computer science, and philosophy. In 1952, Alan Turing, the father of computer science and artificial intelligence, proposed the rudimentary concept of artificial life, and he proved that the relatively simple chemical process can generate a new order from a homogeneous organization[2]. In addition, John Von Neumann proved that the self-replicating-based automata can be established in principle by creating the self-reproducing and computation-universal cellular automata[1,3,4], though the algorithm of self-reproducing-based automata is too complicated to be carried out by the contemporary computation facilities[5]. In 1970, John Conway developed an example of cellular automata – "Game of Life" by implementing several simple rules. Through the natural combination of these simple rules, the unpredictable complex extension and alteration can be generated[6]. In 1980s, Stephen Wolfram proved that the complete evolution of the cellular automata consists of the homogeneous status, periodic loop, chaotic status and the structure of localization and persistence[1]. In 1987, Christopher G. Langton introduced the phrase "Artificial Life (AL, A-Life, or Alife)" at the first "Workshop on the Synthesis and Simulation of Living Systems" at the "Los Alamos National Laboratory"[7]. In 1994, the first international official journal of artificial life – Artificial Life was published by "International Society of Artificial Life (ISAL)", and at present the issues of Artificial Life spans "the hierarchy of biological organization, including studies of the origin of life, self-assembly, growth and development, evolutionary and ecological dynamics, animal and robot behaviour, social organization, and cultural evolution"[8]. Further, the advanced research works of artificial life are still working on till the present day[9,10,11,12,13].

The property of artificial life

So far as discipline of Computer Science is concerned, the root of artificial life in computer science originates from artificial intelligence (AI) and machine learning, and the purposes of artificial life attempt to realize the essentially general properties of living systems and make the essential property of emergent behaviors clear as far as possible by the simulation of the living process of living systems. Through the simulation of living systems in the artificial environment, the inherent behavioral characteristics of

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living systems can be potentially exhibited. Basically, the fundamental behaviors of natural living systems are mainly characterized by self-reproduction, self-organization, chaotic dynamic, environmental adaption and the evolution of complex adaptive structures[1,14]. In addition, these artificial life systems can be synthesized in software (software-based artificial life), hardware (hardware-based artificial life), or wetware (biochemical-based artificial life)[1,8].

So far as the software-based artificial life is concerned, the simulation of natural living systems is carried out by computer models (or computational algorithms), and the techniques comprises cellular automata (e.g. "Game of Life" proposed by John Conway and "Tierra" proposed by Thomas Ray[15] and neural networks[1,16]. In addition, an example of 'life-forms' based on the cellular automata and its evolving process can be illustrated in the Figure 1[17]. So far as the hardware-based a life is concerned, "it is primarily concerned with various forms of autonomous agents, such as robots, for the purpose of synthesizing autonomous adaptive and intelligent behaviour in the world"[1,16]. So far as the biochemical-based artificial life is concerned, it involves the discipline of "Synthetic Biology", such as the creation of synthetic DNA[1].

The nature of artificial life modelling

The nature of artificial life modelling is different from that of the traditional biological system modelling, because the nature of the traditional biological system modelling is established on the study of "life-as-we-know-it", based on the constrained living foundation. However, the nature of artificial life modelling is not only established on the study of "life-as-we-know-it", but also that of "life-as-it-might-be", to seek for the general principle underlying the living process as well as the property of emergent behaviour[18]. As for the definition of artificial life, two viewpoints are arisen, including strong artificial life and weak artificial life. As the aspect of strong artificial, John Von Neumann stated that "life is a process which can be abstracted away from any particular medium"[19,20], and which can be created by applying inorganic matter via several simple rules. As the aspect of weak artificial life, "life (or living process) cannot be generated outside of a carbon-based chemical solution, but its processes could be understood by mimicking it in computer simulations" [19,20].

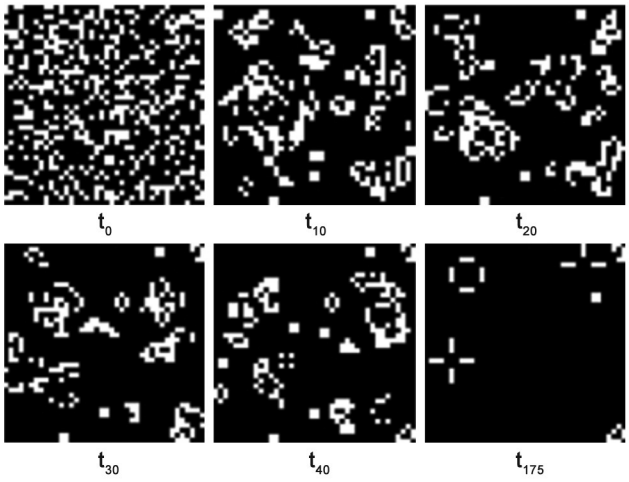

Fig. 1 — The evolving process of 'life-forms'[17]

The relationship between artificial life and artificial intelligence

As mentioned in the previous content, artificial life has roots in artificial intelligence and machine learning, especially for the software-based artificial life, and this is because some machine learning algorithms are applied for doing the simulation of living system as a result of their adaptive learning ability, such as genetic algorithm (GA) and genetic programming (GP). However, in artificial intelligence, these machine learning algorithms (GA and GP) are usually used for the optimization purpose to find the global minimum of the target function or system[21]. It seems there is certain overlapping between artificial life and artificial intelligence, and it is easy to be confused between artificial life and artificial intelligence. Stern stated that the difference between artificial life and artificial intelligence is that artificial life has applied a bottom up approach to observe the fundamental behaviour of natural living systems in the simulation, but artificial intelligence has applied a top down approach to learn the system behaviour by training data[22]. However, as the aspect of an artificial intelligence researcher, it cannot be completely agreed by this viewpoint. As for machine learning algorithms (core mechanism of artificial intelligence), machine learning algorithms are generally used for solving the pattern recognition problems, and machines learning algorithms based on learning type consists of supervised learning, unsupervised learning, and semi-supervised learning[23]. Supervised learning algorithms have the feature of top down approach, because the a priori knowledge is available in advance, and the unsupervised learning algorithms have the feature of bottom up approach, because the a priori knowledge is not available in advance. In addition, the hierarchical clustering algorithms are also the bottom up approaches. Therefore, exactly speaking, artificial intelligence consists of both top down approaches and

bottom up approaches, and it depends on the learning type. Also, the software-based artificial life only used the bottom up approach because the a priori knowledge is not available in advance.

Summary

To sum up, artificial life applies the synthetic methodology instead of analysis methodology to observe the living process of living systems in the artificial environment and make the essential property of emergent behaviors clear. Meanwhile, the nature of artificial life is not only established on the study of "life-as-we-know-it", but also that of "life-as-it-might-be". In that, the fundamental property of natural living systems can be effectively discovered by the comprehensive process based on "life-as-it-might-be". In addition, the essence of life lies in the form rather than substance. Undoubtedly, life cannot be taken from the substance, but life has to put more focus on the process. So far as the relationship between software-based artificial life and artificial intelligence is concerned, the relationship is close. Moreover, the research objective of artificial life focuses on the simulation of behavioural characteristics. However, computer models cannot become the living body, but it can become a powerful tool for artificial life research. In addition to exhibit the fundamental living behaviours, it also can potentially exhibit the specific behaviours, such as self-reproducing, self-organizing and self-learning. Most important of all, the study of artificial life cannot only bring the contribution to explain the living behaviours and explore the origin of life, but it also provides a new approach to biological research.

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