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Common Ancestor and Genetic Diversity in Penna Model

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Abstract. The characteristic of individual is described by the Penna model. Based on information entropy and the Penna model we define the entropy in the Penna model to discuss common ancestors and genetic diversity for two reproduction modes with and without mutation. About the problem of common ancestor, we find that all living individuals at any time step have a set of common ancestors which belongs to different times. They have the most recent common ancestor and earlier common ancestors. The analysis of genetic diversity shows that the complexity of ecosystems is caused by mutations and there is no contribution of sexual reproduction to conserving genetic diversity at long time scales. Moreover, in stable environment genetic diversity in asexual reproduction mode is higher than that in the sexual case.

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Key words: Penna model, entropy, common ancestor, genetic diversity, mutation.

1 Introduction

The research of common ancestor has always been the focus of the academia. In the Archaeology field, fossils are an important tool to study common ancestor for scientists [1]. With the development of gene technology, a new method to reveal the secrets of biological evolution is DNA sequence analysis [2–4]. Some other theoretical studies about common ancestor are based on mathematics and simulation [5–11]. For example, Rohde et al. suggest that all present-day human have one most recent common ancestor and earlier exactly the same set of common ancestors [5].

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Recently, there are many researches about biodiversity including species diversity [12–14] and genetic diversity [14–16]. Tilman et al. discuss the diversity and stability in plant communities [12]. They use data from a long-term biodiversity experiment with plant communities to show that diverse systems can be both stable and unstable. Emerson and Kolm show that species diversity can drive speciation [13]. Global efforts to conserve species have been strongly influenced by the heterogeneous distribution of species diversity across the Earth. This is manifest in conservation efforts focused on diversity hotspots [16–18]. The conservation of genetic diversity within an individual species [19, 20] is an important factor in its survival in the face of environmental changes and disease. Therefore, genetic diversity within species is an important subject in the research of biodiversity. Rauch and Bar-Yam show that diversity within species is distributed unevenly by simulation [15], which implies that diversity loss owing to severe extinction events is high, and focusing conservation efforts on highly distinctive groups can save much of the diversity. In this paper, the biodiversity under consideration is also about the genetic diversity within species.

Penna presents a simple model for biological aging based on bit strings [21]. The model works under the effect of the Verhulst factor, mutations, death by genetic diseases or age and a minimum reproduction age. The sexual Penna model introduced by Stauffer et al. [22, 23] corresponds to a reproductive regime of diploid organisms, the population being divided into males and females. Makowiec et al. discuss the "Eve effect" in the Penna model [24], which is also studied in a few other papers [25–27]. Moreover, information entropy proposed by Shannon is used to discuss the uncertainty of events and the amount of information [28].

Based on the Penna model and information entropy we define the entropy in the Penna model to discuss common ancestor so-called "Eve effect" and genetic diversity for asexual and sexual reproduction. From the results we find that all present-day individuals within a species have exactly the same set of ancestors which belongs to different times and mutation is the basic condition of conserving genetic diversity.

The paper is organized in the following way. In Section 2, we give the model of entropy in the Penna model to discuss common ancestor and genetic diversity for asexual and sexual reproduction. In Section 3, we draw some conclusions from this study.

2 The entropy in Penna model

2.1 Penna model [21–23]

2.1.1 Asexual model

Each individual of the population is described by a bit string of zeros and ones, where each bit position corresponds to a year. The size of this bit string is $A_{\max}$ that means each individual will die when its age becomes $A_{\max}$. Genetic diseases are represented by a bit "1" in the strings. Each "year" one more bit position is looked at. There is a