A Review on Pre-Processing Methods Utilized for Bone Age Estimation Models

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Abstract:
In the present time, bone age estimation models are gaining popularity to measure the biological age of children's bones by evaluating their bones. In order to accomplish this goal, the researchers read the RSNA dataset of bone images. Next, the researchers pre-process the dataset to identify the region of interest. Further, machine learning algorithms are utilised to predict bone age. In this paper, we have studied and analysed the pre-processing methods used in the bone age estimation models because pre-processing methods enhance the dataset quality and effectively determine the region of interest, which enhances the machine learning algorithm performance to determine the bone age. This research primarily explores three areas, namely filtering, enhancement, and segmentation, in the pre-processing methods. From the analysis, we found that the metaheuristic algorithm is utilised to enhance the pre-processing methods by determining their optimal parameters. Finally, open research challenges are defined to enhance the pre-processing methods.

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1. Introduction

Children's development and maturation processes are often connected, but they cannot be viewed as a single process since they are not linear and may occur at different times. The biological age and chronological age (CA) might differ due to a variety of disorders, including growth hormone (GH) insufficiency, thyroid hormone deficit, delayed puberty, and sometimes even in healthy children. This is because at they are controlled by a multitude of variables, including hormones, sex hormones, insulin-like growth factor-1, genes, and adrenal steroids including testosterone, cortisol, and dehydroepiandrosterone (Prokop-Piotrkowska et al. 2021). In the field of pediatric endocrinology, it is particularly crucial to evaluate a child's development and puberty by their biological age as opposed to their chronological age. For decades, physicians have therefore been searching for a reliable indicator of a child's pace of maturation. Although menarche age is a reliable biological measure of adulthood, it only applies to half of the population and is a one-time occurrence. In their everyday work, dentists—primarily orthodontists—use the Demirjian or Willems scale to determine dental age, however, other practitioners haven't been shown to find this method to be trustworthy. Only throughout adolescence are sexual characteristics—such as those determined by placing a person on the Tanner scale—useful and very subjective. Bone age (BA) is the sole biological measure of maturity that is accessible from birth to adulthood.

Bone Age (BA): In paediatric endocrinology, BA is a useful technique for the clinical evaluation of patients, particularly those with growth and puberty abnormalities. Numerous factors, such as height velocity, menarche, muscle

mass, and bone mineral mass, correlate more favorably with BA than with CA (Nadeem et al. 2020). A delayed biochemical reaction (BA) is often seen in cases of growth hormone shortage, hypothyroidism, malnourishment, and chronic illnesses. On the other hand, when there is a persistent rise of sex steroid levels, BA is progressed in several disorders, such as congenital adrenal hyperplasia and premature puberty. In children who are overweight, have a tall height, or have premature adrenarchy, BA may also be somewhat accelerated. BA is often further advanced in genetic overgrowth disorders, such as Marshall-Smith syndrome, Sotos syndrome, and Beckwith-Wiedemann syndrome. In every case, BA advancement or delay relative to CA is a long process, therefore BA may not be changed in quick evaluations after the initial symptoms of a problem and should be examined temporally. Furthermore, BA is used to estimate CA in forensic and legal medicine, such as in the case of unaccompanied adolescents without documentation or asylum applicants. In these situations, a thorough age determination utilizing exact techniques is essential. A child's access to school, healthcare, and other types of assistance may be further restricted if they are incorrectly evaluated as adults.

The main motive of this research is to study and analysed the various pre-processing methods are utilized for bone age estimation models. In the literature, filtering, enhancement, and segmentation are the most popular approaches are utilized for pre-process the dataset and further deployed for train the machine learning models. In this research, a critical analysis of various methods is done based on various factors and based on its open research challenges are defined which defines how these methods is enhanced in the future. From the open research challenges, we found that metaheuristic algorithm and machine learning are effectively enhances the pre-processing methods according to the characteristics of the input database.

The remaining paper is categorized as follows. Section 2 shows the critical analysis of the pre-processing methods. Based on the critical analysis, open research challenges and conclusion is defined in Section 3-4.

2. Critical Analysis of Pre-Processing Methods

The main motive of the pre-processing method is to determine the region of interest from the input database image. To accomplish this goal, various pre-processing methods are utilized in the bone age estimation models. Table 1 shows the critical analysis of the pre-processing methods based on the database, pre-processing method, and influence drawn from it.

Table 1: Critical Analysis of the Pre-Processing Methods

Reference	Database	Pre-Processing Method	Influence Drawn
(Rajitha, B. and Agarwal, S., 2022)	RSNA 2017	Wavelet Packet transformation for noise reduction, histogram equalization, and segmentation using the clustering method	They are effectively removing the noise from the image and k-mean clustering method is utilized for determine the region of interest in the images However, they have utilized the conventional image enhancement method for enhance the image.
(Deshmukh, S. and Khaparde, A., 2022)	RSNA 2017	U-Net along with class topper optimization and whale optimization	In their work, they have optimized the U-net activation function using the metaheuristic algorithm. However, no noise reduction and enhancement are done in their work.
(Salim, I. and	RSNA 2017	Image annotation	In their work, image annotation along

Hamza, A.B., 2021)		and segmentation	with segmentation is done using the U-net network. In their work, no optimal tuning of activation function of U-Net is done.
(Gao et al. 2020)	RSNA 2017a	Histogram Equalization, Laplace filter, Gaussian Filter, Gamma transformation, U-Net for Segmentation	In their a number of enhancement and filtering methods are deployed for enhance the characteristics of image. Further, optimal region of interest is determined using the U-net.
(Pan et al. 2020)	RSNA 2017	U-Net	In their work, U-net is utilized to segment the database images to train and test the bone age estimation model using the machine learning.

3. Open Research Challenges

From the critical analysis, we found that segmentation is the most important part of the pre-processing method to determine the region of interest. In order to accomplish this goal, k-mean clustering and U-Net is the most preferred approach. After segmentation, enhancement is the second important part of the pre-processing method to enhance the characteristics of the image using histogram equalization/gamma correction. In the last step, filtering is also done in the pre-processing method to remove the noise from the images using Laplace/gaussian/wavelet methods. In all approaches, conventional methods are used, which preprocess the dataset images at the same level. However, in the real scenario, the image characteristics vary from image to image. Thus, adaptive pre-processing methods are required that process the image according to its characteristics. In order to overcome this issue, the most appropriate solution is to utilise metaheuristic algorithms for pre-processing methods. Below is a detailed description of the metaheuristic algorithm.

Optimization approaches known as metaheuristic algorithms are developed to provide practical solutions for a wide variety of optimization issues (Khanduja, N. and Bhushan, B., 2021). There are several ways in which these algorithms differ from other optimization methods. First of all, unlike gradient-based search algorithms, they are derivative-free, which means that no derivatives need to be calculated in the search space. Because of this, metaheuristic algorithms are significantly easier to use, more adaptable, and have a greater ability to avoid local optima. This makes them ideal for addressing difficult optimization jobs. Another feature of metaheuristic algorithms is their stochastic nature, which means they start the optimization process by producing unpredictable outcomes. This increases the likelihood that the algorithms can efficiently and rapidly explore the search space without experiencing premature convergence. To do this, metaheuristics strikes a compromise between profit and exploration. In the analysis phase, the algorithms conduct local searches in the places that were exhaustively examined during the discovery phase to identify the highest gilt-edge resolution. The adaptability and flexibility of metaheuristic algorithms are their unique and main benefits. They are the ideal solution for a wide variety of optimization issues across several technical and scientific domains since they are readily adjustable to meet the specific requirements of any particular challenge. Next, framework of metaheuristic algorithm is explained (Houssein et al. 2021).

A metaheuristic searches for solutions that are close to ideal by searching the search space to optimize efficiency. They are built on a search process technique. Any artificial or natural system under study might serve as an

inspiration for the approach. This may originate from a variety of places, including the annealing process in metallurgy and ant foraging habits. We must pursue both scientific and technical objectives while defining a metaheuristic around a search method. To represent the process behind an inspiration like a swarm of ants is the scientific objective. Engineering aims to create systems that can effectively address real-world issues. Defining a general framework is unrealistic, but we can talk about certain distinguishing features. In any metaheuristic approach, striking the right balance between exploration and exploitation is essential. To avoid choosing less-than-ideal answers, exploration involves looking at the whole viable area as much as one can. Exploitation is the process of looking around a promising area in search of the best solution. The flowchart for exploration and exploitation is shown in Figure 1.

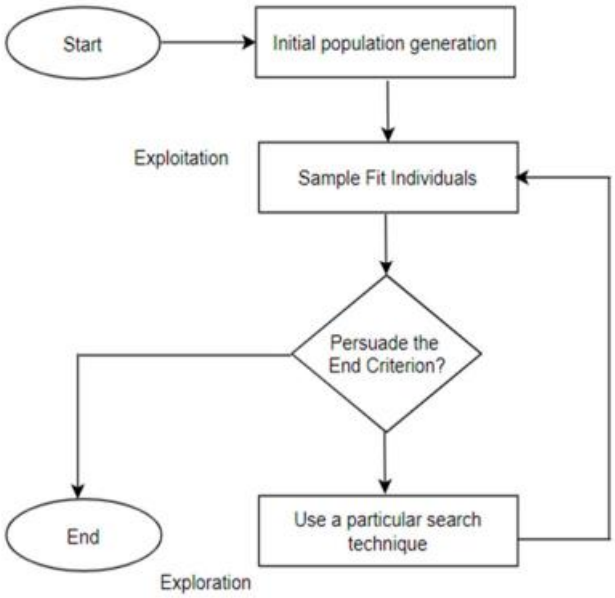

Figure 1: Exploitation and Exploration flowchart of the Metaheuristic Algorithm

To assess the potential solutions, we typically use a fitness function in almost all of these metaheuristics. The best solutions are sampled so they can focus on exploitation. Additionally, we include randomization and stress exploration by using certain components of the search technique. This is unique to each search technique and hence impossible to convey with a generic formulation. These methods let us solve real-value functions with more than one variable without having to use their gradient. This is important since it means these algorithms can tackle non-continuous, noisy, and changing optimization problems

4. Conclusion

In this research, we have studied and analysed the pre-processing utilised in the bone age estimation models. In the pre-processing method, image noise, quality, and segmentation are important tasks. In order to accomplish these tasks, filtering, enhancement, and clustering methods are deployed. However, the performance of these methods can be enhanced by utilising the metaheuristic algorithms for them. Finally, an overview of metaheuristic algorithms is given, which helps the researchers understand how these algorithms are used for pre-processing methods.

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