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Segmentation of Carpal Bones Using Gradient Inverse Coefficient of Variation with Dynamic Programming Method

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***Abstract*— Segmentation of the carpal bones (CBs) especially for children above seven years old is a challenging task in computer vision mainly because of poor definitions of the bone contours and the occurrence of the partial overlapping of the bones. Although active contour methods are widely employed in image bone segmentation, they are sensitive to initialization and have limitation in segmenting overlapping objects. Thus, there is a need for a robust segmentation method for bone segmentation. This paper presents an automatic active boundary-based segmentation method, gradient inverse coefficient of variation, based on dynamic programming (DP-GICOV) method to segment carpal bones on radiographic images of children age 5 to 8 years old. A mapping procedure is designed based on *a priori* knowledge about the natural growth and the arrangement of carpal bones in human body. The accuracy of the DP-GICOV is compared qualitatively and quantitatively with the de-regularized level set (DRLS) and multi-scale gradient vector flow (MGVF) on a dataset of 20 images of carpal bones from University of Southern California. The presented method is capable to detect the bone boundaries fast and accurate. Results show that the DP-GICOV is highly accurate especially for overlapping bones, which is more than 85% in many cases, and it requires minimal user's intervention. This method has produced a promised result in overcoming both issues faced by active contours method; initialization and overlapping objects.**

***Keywords*— carpal bone; segmentation; active contour; gradient inverse coefficient of variation; dynamic programming.**

I. INTRODUCTION

Bone age estimation (BAE) is a method of assigning a level of biological maturity to a child. It is widely used in diagnosing heredity diseases and growth disorder. Besides, it is an essential tool in the assessment of children with growth delay and in following response to therapy. BAE is also being used in cases of unregistered child, under-age sports tournaments, juvenile court cases, asylum-seeking children, and forensic practice. In general, the BAE was derived by two methods, comparison of the radiography of hand bones with a reference using Greulich and Pyle atlas [1] or by the numerical scoring system of Tanner-Whitehouse [2]. Both methods are laborious and prone to inter- and intra-observer variability between experienced and inexperienced radiologist. Hence, an automated and consistent method using a computerized BAE (CBAE) method is needed.

There have been many attempts to computerize the BAE procedure ranging from semi-automated in which active shape models are used on the implementation of the TW2 system [3] and distance ratios are supplied to neural networks for BA calculation [4] to fully automated system using integrated clinical system with Picture Archiving Communication Systems (PACs) [5], fuzzy approach on carpal bones [6], particle swarm optimization [7], neural networks to produce a BAE based on radius and ulna bones [8], and neural networks to extract the features of carpal bones [9]. Most CBAE methods focus on analyzing the bones of the phalanges, metacarpal, and wrist for children from 0 to 18 years old. These types of bones are popular in estimating the bone age because the layout of these bones is simple, and they are not tended to overlap onto one another. Apart from those bones, estimation of bone age using carpal bones receives less attention because the structure of the carpal is complicated especially when the child starts to grow into teenage years. One of the biggest challenges in the carpal bone analysis is when the carpal bones are getting bigger and too close to one another until some of them are overlapped [10]. Fig. 1 shows a hand radiograph image of a 7 years old Asian male. Here, the ground truth (GT)