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EIT Image-Based Bladder State Classification for Nocturnal Enuresis

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Abstract: In this paper, we propose the use of electrical impedance tomography (EIT) to support children with nocturnal enuresis. We perform the first image-based threshold classification for determining the bladder state of 'not full' or 'full'. The results demonstrate the strong promise for EIT as an aid for nocturnal enuresis.

1 Introduction

Nocturnal enuresis (also known as bedwetting or NE) is a common childhood condition with an overall prevalence between 9-12 % [1]. Where the condition is associated with daytime lower urinary tract symptoms, NE can constitute up to 40 % of paediatric urology clinic visits [2]. The impact of NE on the child is both medical and psychological, severely degrading a child's quality of life [3].

Common treatments include pharmacological therapies and devices that alert after urination has occurred [4]. These treatments are reactive and have high relapse or discontinuation rates [4, 5].

Electrical impedance tomography (EIT) is a low-cost, portable, and non-invasive medical technology that can be used to determine the bladder volume of patients [6]. The technology offers the potential to proactively treat nocturnal enuresis in children.

Image-based classification allows the bladder volume to be determined. Image segmentation [7] and metrics such as the average conductivity index [8] and global impedance [7] have been previously related to bladder volume using EIT. However, for NE, the exact bladder volume does not need be determined; it is only necessary to detect when the bladder is nearing full. In this paper, we perform the first image-based threshold classification in bladder monitoring using EIT to determine the bladder state of 'full' or 'not full'.

2 Methods

The electrical impedance dataset from Dunne *et al.* [9], with varying signal-to-noise ratio (SNR) and bladder volume, formed the basis for the image dataset in this paper. Using a SNR of 40 dB (one of the lower SNRs for existing EIT hardware [10]) and the GREIT image reconstruction algorithm [11], 99 2D noisy images were formed with a non-noisy reference image of an empty bladder (40 ml bladder). The bladder volumes used were {60:40:260, 280, 300:20:420} ml. The boundary between full and not full bladder volume was taken as 300 ml. The mean pixel intensity was then calculated for each image.

3 Results & Discussion

The bladder states of full and not full can be separated based on the mean pixel intensity alone, as shown in Figure 1. While some overlap is present in the distributions, multiple thresholds may be used to refine the certainity of predicting full or not full bladders. Probablistic machine learning may then be used within the uncertainity region to improve performance. The performance of the mean pixel intensity for threshold classifcation is shown in the receiver operating characteristic (ROC) curve in Figure 2, demonstrating that a good trade-off between true positive and false positive rates can be achieved.

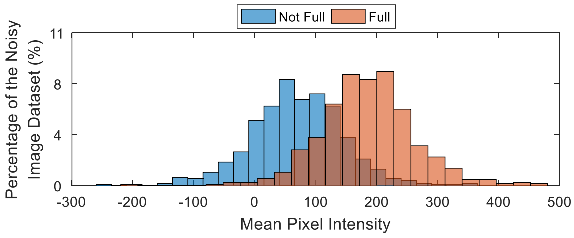

Figure 1: A histogram comparing the mean pixel intensity of each image for the two types of classifications: a not full bladder (blue) and a full bladder (orange).

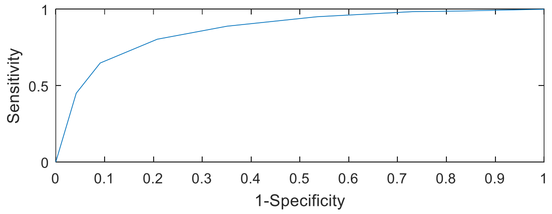

Figure 2: ROC curve for threshold classification using the mean pixel intensity of the reconstructed images.

4 Conclusions

This paper has proposed the use of EIT for support of nocturnal enuresis, and has shown that simple threshold classification based on reconstructed bladder images can be used to predict the bladder state of 'full' or 'not full'.

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