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Alcoholism detection by medical robots based on Hu moment invariants and predator–prey adaptive-inertia chaotic particle swarm optimization☆

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ABSTRACT

This work is aimed to develop the key algorithms used in medical robots, which can detect alcohol use disorder from structural magnetic resonance imaging of brains. We enrolled 30 alcoholic participants and 30 nonalcoholic participants. In the algorithm stage, we suggested to use Hu moment invariant to extract global features, and use single-hidden layer neural-network as the classifier. Afterwards, we proposed a novel predator–prey adaptive-inertia chaotic particle swarm optimization algorithm to train the classifier. The ten-fold stratified cross validation showed that our method achieves a sensitivity of $90.67 \pm 3.16\%$, a specificity of $91.33 \pm 3.06\%$, and an accuracy of $91.00 \pm 1.41\%$. Our results are better than genetic algorithm, firefly algorithm, and particle swarm optimization. This proposes algorithm is effective in alcoholism detection. It can be installed on medical robots.

1. Introduction

Alcoholism represents any problems resulting from drinking alcohol [1]. It is also called alcohol use disorder (AUD). Alcoholism is diagnosed if following conditions are present: usage results in social and health problems, usage results in not fulfilling responsibilities or risky situations, drinking large amounts or over a lengthy period, taking considerable time to acquire and drink alcohol, heavy dependence and urgent desire of alcohol, alcohol withdraw syndrome occurs when reducing or stopping, alcohol tolerance, etc.

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Table 1
Demographic characteristics.

	Alcoholic		Nonalcoholic	
	Women ($n = 13$)	Men ($n = 17$)	Women ($n = 15$)	Men ($n = 15$)
Age (y)	58.3 ± 9.0	55.8 ± 9.3	55.9 ± 8.5	54.8 ± 8.4
Education (y)	9.8 ± 1.9	9.4 ± 1.7	9.3 ± 2.7	9.1 ± 2.7
DHD (y)	13.3 ± 3.8	19.1 ± 5.7	0.0 ± 0.0	0.0 ± 0.0
DDE (gram/d)	198.2 ± 67.2	292.6 ± 96.0	6.5 ± 5.0	4.2 ± 4.0
LOS (y)	10.2 ± 5.6	6.2 ± 3.2	N/A	N/A
AUDIT	24.5 ± 4.6	25.4 ± 5.3	1.6 ± 2.3	1.9 ± 2.4

(DHD = duration of heavy drinking; DDE = daily drinks of ethanol; LOS = length of sobriety; AUDIT = alcohol use disorders identification test).

Chronic exposure to alcohol exert negative effects on the whole body, especially the brain, pancreas, liver, heart, and immune system. It may lead to mental illness, Wernick Korsakoff syndrome, liver failure, fetal alcohol spectrum disorder, celiac disease, cardiovascular disease, social problem, etc.

Within the brain, the patients with alcoholism take smaller volumes of both gray matter and white matter. Particular, older alcoholics show greater gray and white matter volume deficits compared to age-matched controls than young alcoholics. Moreover, the cerebellum is affected in uncomplicated alcoholics, with shrinkage in large neurons in anterior superior vermis [2]. Damage to cerebellum may cause not only truncal deficits and imbalanced gait, but also impairment in problem solving and working memory.

Usually the radiologists are difficult to perceive the slight shrinkage of AUD patients. Nevertheless, the medical robots can help find the difference between AUD and healthy controls. Scholars have already developed numerous medical robots in assisting making diagnosis. For example, Lue et al. [3] used firefly in minimal access robotic surgery, in order to improve accuracy of intraoperative diagnosis of endometriosis. Boman et al. [4] developed a robot-assisted remote echocardiographic examination and teleconsultation. Ahn et al. [5] offered a robotic system with sweeping palpation and needle biopsy for prostate cancer. Fisher et al. [6] provides a review of state-of-the-art medical robotic systems for use in conjunction with intraoperative magnetic resonance imaging. Mariappan et al. [7] provides a medical tele-diagnosis (MTR) tool, which is an internet based communication and navigation system. Nayak et al. [8] developed a brain image classification algorithm that can be installed on medical robots.

Nevertheless, there are no medical robots for detecting AUD patients. In this study, we aimed to develop the key algorithms in an AUD detection robot, which can help assist make diagnosis from magnetic resonance imaging of patient brains. For the authors' best known, this study is the first to equip alcoholism detection algorithm to medical robot. Other contribution is we proposed a novel optimization algorithm for training the classifier. In total, the contribution of this study is two-fold. (i) We designed a new algorithm that can detect alcoholism patients. (ii) We proposed an improved particle swarm optimization algorithm to enhance the classification performance.

The structure of the remainder is organized as follows: Section 2 gives the subjects, imaging protocol, and preprocessing methods. Section 3 offers the Hu moment invariants. Section 4 gives the classifier and proposes a new optimization algorithm to train it. Section 5 gives the results and discussions. Section 6 gives the concluding remarks.

2. Materials

2.1. Subjects

We enrolled 30 abstinent long-term chronic alcoholic participants (17 men and 13 women) and 30 nonalcoholic control participants (15 men and 15 women). Participants were enrolled through flyers posted in Nanjing Children's Hospital, Jiangsu Province Hospital and Nanjing Brain Hospital, as well as the internet-based advertisements. The subject enrollment and MRI scanning cost in total three years. In the future, we shall enroll extra subjects. At present the 60-subject is enough for statistical analysis. Their demographic characteristics are presented in Table 1.

The research was approved by the Institutional Review Board of the participating hospitals. Informed consent was obtained from each participant.

The applicants went through a medical history interview to guarantee they met the inclusion criteria. Qualifying applicants received the computerized diagnostic interview schedule version IV, which ascertains the presence or absence of major psychiatric disorders. Applicants were excluded if mandarin is not their first language, if they were left-handed, or if they had HIV; stroke; bipolar; Wernick Korsakoff syndrome; cirrhosis or liver failure; epilepsy or seizures unrelated to alcoholism; head injury with loss of consciousness more than 15 minutes unrelated to alcoholism; schizophrenia; depression; and other psychotic disorders. Finally, all participants were given the Alcohol Use Disorder Identification Test (AUDIT) and alcohol use questionnaire. The unit "ounce" was transformed to gram, since ounce is not widely used in China.

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