# Research Progress and Prospect of Acupuncture Robot

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**Abstract:** Acupuncture is a unique traditional medical technique in China. Acupuncture robot research has been gaining increasing attention, yet there is a lack of systematic summary and analysis. This paper therefore systematically reviews three core technologies in acupuncture robotics: (1) intelligent acupoint localization using electrical impedance measurement and image recognition, (2) multi-mode needle insertion mechanisms (mechanical ejection and motor-driven systems), and (3) advanced stimulation techniques (manual manipulation simulation, transcutaneous electrical acupoint stimulation, and laser stimulation). The research concludes that despite advancements, acupuncture robot research still faces challenges such as limited international collaboration, high development costs, and difficulties in core technology breakthroughs. Future acupuncture robots should integrate intelligent diagnosis, syndrome differentiation, precise localization, intelligent needle manipulation, accident handling, and human-machine interaction to form a comprehensive system, advancing clinical practice.
***Keywords*:** Acupuncture; Acupuncture robots; Moxibustion robots

## 1. Introduction

Acupuncture therapy has proven effective in managing chronic diseases, controlling pain, and treating mental illnesses, gaining popularity among patients due to its affordability, stable and long-lasting effects, and minimal side effects. However, the lengthy training and high costs associated with acupuncturists result in a shortage of skilled practitioners [1]. Acupuncture robots, if successful in replacing or assisting acupuncturists, could ease their workload [2].

Moreover, the subjective nature of traditional acupuncture therapy, which relies on the "deqi" sensation for evaluation, lacks objectivity and quantitative standards, hindering international recognition [3]. The development of acupuncture robots aims to address this issue, enhancing the repeatability and objectivity of acupuncture treatments and paving the way for further research. This paper discusses the current research status of acupuncture robots, summarizes their limitations, and offers insights for future technological advancements and innovations.

## 2. Acupuncture Robot

### 2.1 Acupoint Localization

Low Resistance Characteristic: In the 1950s, Japanese scholars discovered the low resistance characteristic of acupoint skin and invented the DC meter [4]. Yang et al. improved the bi-electrode method and developed an embedded acupoint identification device [5]. However, DC power can cause protein denaturation and pain [6]. Yang et al. designed the four-electrode method using AC power to solve this problem and improve measurement stability [7]. Zhang's dual four-electrode method further overcame interference [8]. Low-resistance acupoint localization methods can objectively reflect position, patients may experience discomfort, individual differences can affect accuracy, and it takes time to complete, unable to meet emergency needs for rapid location.

Image Processing: Image processing technology converts the "cun" system into a digital positioning method by matching human body shapes or detecting feature points. Zhang et al. combined template matching and camera calibration to achieve stable acupoint tracking [9]. Wang adopted a visual acupoint location method combined with deep learning to locate acupoints in complex areas [10]. Liu et al. combined RCNN with CBAM to improve the accuracy of back acupoint positioning [11]. Zhao et al. used the OpenPose network combined with a gradient boosting decision tree algorithm to achieve automatic back acupoint positioning [12]. Image-based positioning methods do not require direct skin contact, and can enhance accuracy by combining medical imaging data, achieving standardized positioning across different body types and poses. This technology offers significant advantages and aligns with future trends in acupoint identification.

### 2.2 Needle Insertion

Mechanical Ejection: Wang et al. designed a continuous needle supply device that utilizes compressed springs for rapid needle insertion and ensures stable needle supply [13]. Wang et al. invented an acupuncture ejection needle inserter that uses spring plate ejection force for needle insertion and solved the quantification problems of angle, force, and depth [14]. Mechanical ejection needle insertion can reduce patient pain, but further improvement is needed for subsequent needle clamping techniques.

Motor-driven: In the area of motor-driven needle insertion, Zhang et al. developed an automatic acupuncture manipulator that uses stepper motors to drive ball screw spindles for lifting and twisting movements, and can collect acupuncture parameter data [15]. Chen et al. designed an acupuncture needle inserter that simulates human hand insertion, reduces pain, and is equipped with scale indicators and disinfection mechanisms [16]. Motor-driven needle insertion mechanisms not only alleviate patient pain but also have the ability to connect to Bluetooth and networked devices, laying the foundation for acupuncture technique databases and high automation.

Existing acupuncture devices mostly allow for vertical insertions only, making it difficult to perform oblique or horizontal insertions, and are unsuitable for complex areas; they lack force-sensing devices to respond to accidents; and the absence of needle storage and replacement mechanisms affects needle retention and the continuity of treatment efficacy.

### 2.3 Acupoint Stimulation

Acupuncture Technique Stimulation: Wang et al. innovated an acupuncture needle holder capable of electric insertion, lifting-thrusting, twisting, and automatic loading [17]. Ma et al. employed digital signal processors and servo motors to simulate and quantify acupuncture techniques [18]. Wang et al.'s device further integrates warming needle moxibustion functions [19]. Yu et al. developed a human-computer interaction system using a 6-DOF robot for precise acupuncture simulation, trajectory planning, and efficient automation [20]. Yet, acupuncture robots still struggle with simulating auxiliary techniques like tracing and plucking, impacting treatment efficacy.

Transcutaneous Electrical Acupoint Stimulation (TEAS): Electroacupuncture therapy emerged to address the shortage of acupuncture physicians [21]. Zhang et al. introduced a home-based system for automatic acupuncture point recognition and treatment using electrical resistance [22]. Hong et al. created an intelligent system that adjusts electro-acupuncture parameters based on sensor data [23]. He et al. designed an acupuncture robot using microcurrents, replacing manual manipulation [24]. Electroacupuncture is effective for certain treatments and pain relief but requires precise intensity control to avoid adverse effects.

Laser Stimulation: Laser acupuncture, a fusion of traditional acupuncture and modern technology, has been in use for over three decades [25]. Chang et al.'s novel system simulates lifting and thrusting techniques with significant experimental results [26]. Lan et al. leveraged image processing for flexible multi-point stimulation [27]. Li et al.'s semiconductor laser simulator adjusts power via current control to mimic lifting and thrusting [28]. Laser acupuncture is safe, painless, and avoids needle-related risks but may not suffice for diseases needing intense needle sensation.

## 3. Conclusion

Despite advancements, acupuncture robot research faces challenges: limited international research hinders industry standardization; high research costs stem from the acupuncture technique diversity and extensive acupoint system, demanding large-scale dataset training; core technology breakthroughs, like "deqi" judgment and acupuncture parameter quantification, remain difficult; clinical utilization is low due to low research conversion; advanced sensor integration is necessary for safety, preventing needle bending and breaking; patient-practitioner communication gaps hinder market acceptance; and automation is still limited, needing manual support.

Future acupuncture robots should integrate intelligent diagnosis, syndrome differentiation, precise localization, intelligent needle manipulation, accident handling, and human-machine interaction to form a comprehensive system, advancing clinical practice.

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