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The Integration of AI In TCM

The Convergence of Artificial Intelligence and Traditional Chinese Medicine

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## The Integration of AI and TCM

Traditional Chinese Medicine (TCM) is a comprehensive, holistic medical system developed over 2,000 years. Grounded in balance, harmony, and the flow of Qi (vital energy), TCM offers a time-tested approach to diagnosing, preventing, and treating disease. It employs a range of experience-based therapies, including acupuncture, herbal medicine, cupping, moxibustion, and dietary treatment, all unified by an underlying theoretical framework based on organ systems (*Zang-Fu*), meridians, and pattern differentiation (*bian zheng*). Over the centuries, TCM has evolved into a respected global health discipline, offering unique insights into health maintenance, chronic disease management, and preventative care.

Today, Artificial Intelligence (AI) is poised to transform TCM by introducing powerful tools to modernise its diagnostic and treatment systems. AI brings new levels of precision, efficiency, and accessibility to a tradition that has historically relied on practitioner intuition and experience. As digital technologies reshape global healthcare, integrating AI into TCM represents an unprecedented opportunity to evolve the discipline while preserving its holistic core.

AI-powered tools are revolutionising traditional workflows. These systems analyse vast amounts of structured and unstructured data, allowing practitioners to recognise subtle diagnostic patterns across complex symptom presentations, match patients to individualised herbal formulas or acupuncture prescriptions and streamline administrative tasks, including recordkeeping and report generation. By automating time-consuming processes, AI allows practitioners to focus more on clinical reasoning, treatment strategy, and human interaction. This improves the quality of care and enhances practitioner well-being and job satisfaction.

A significant contribution of AI to TCM is its support for patient-centred models of care. Traditionally, TCM relies on practitioner insight and long-term patient observation. AI complements this by enabling highly personalised treatment plans based on constitution, lifestyle, and response history, or more time for clinicians to engage in meaningful dialogue, emotional support, therapeutic education and stronger doctor-patient relationships built on trust, compassion, and shared understanding. This patient-centred shift strengthens treatment adherence and outcomes, aligning with global movements toward integrative, whole-person healthcare.

One of the long-standing challenges of TCM lies in its lack of standardised diagnostic procedures. AI is helping to bridge this gap by integrating structured TCM databases with diagnostic algorithms and knowledge graphs, promoting data-driven syndrome differentiation and treatment principles and supporting validation of traditional methods through large-scale analysis and reproducibility. These advances are essential for positioning TCM within modern scientific and clinical standards, enhancing its credibility and supporting its integration into mainstream healthcare.

As healthcare shifts toward value-based models, AI offers TCM practitioners’ tools to reduce costs, optimise resource use, and minimise diagnostic errors. By making traditional practices more efficient, measurable, and transparent, AI contributes to a more sustainable and equitable healthcare future, especially in systems driven by outcomes, quality, and patient satisfaction.

AI is not here to replace Traditional Chinese Medicine—it is here to enhance and meet the demands of a data-driven, digital age. The integration of these two worlds invites interdisciplinary collaboration, clinical innovation, and cultural exchange, reinforcing TCM's continued relevance in 21st-century global health. This book explores the many dimensions of this convergence—from the objectification of TCM diagnosis, to the use of digital systems for research, to the role of AI in modernising acupuncture and herbal medicine, to the revolution of robotics and LLMs, to the modernisation of traditional Chinese Medicine. As we move forward, continued investment, collaboration, and thoughtful application will be essential to realising the full potential of integrating TCM and AI.

## Chapter 1: What is AI?

Artificial Intelligence (AI) is the simulation of human intelligence processes by machines, particularly computer systems, capable of learning, reasoning, analysing, and making predictions. With the ability to process vast amounts of structured and unstructured data, AI excels in data mining, pattern recognition, and predictive modelling. These tools uncover hidden patterns, relationships, and insights that may be difficult or impossible for humans to detect unaided. AI supports:

* **Diagnostics** by analysing patient features such as tongue images, pulse waveforms, and symptom profiles, assisting syndrome differentiation and improving diagnostic consistency.
* **Research** by mining historical and modern literature, mapping multi-compound, multi-target mechanisms, and accelerating drug discovery through network pharmacology and chemical data analysis.
* **Clinical Applications** through intelligent recommendation systems that personalise acupuncture point selection, herbal prescriptions, and treatment plans, tailored to individual patient needs and constitution.

In Traditional Chinese Medicine (TCM), AI holds transformative potential by enhancing precision, objectivity, and personalisation in diagnosis, research, and treatment. AI enables quantifying and modelling TCM’s traditionally experiential practices, revealing the complex interactions and therapeutic pathways of herbal formulations and acupuncture treatments. By synthesising knowledge across eras and modalities, AI empowers a new era of evidence-based, integrative, and globally accessible Chinese medicine, while honouring its holistic foundations.

## Chapter 2: Applications of AI in TCM

AI technologies are revolutionising Traditional Chinese Medicine (TCM) by offering sophisticated tools for data analysis, diagnostic support, treatment personalisation, and knowledge discovery. Integrating cutting-edge models—such as deep learning, graph-based networks, and natural language processing—enables researchers and clinicians to uncover complex relationships within TCM systems and enhance clinical efficacy.

|  |  |  |
| --- | --- | --- |
| Model Type | AI Model | Function |
| Network and Graph-Based Models |  |  |
| Graph Neural Networks (GNNs) | Ideal for modelling the non-linear, relational structure of TCM data (e.g., herb-compound-disease networks). GNNs improve auxiliary diagnosis and enable the identification of new therapeutic pathways. |
| Graph Attention Networks (GATs) | Enhance herb recommendation systems by analysing intricate chemical and pharmacological relationships among herbal components. |
| Hybrid-Scale Graph Contrastive Learning | Applied in formula discovery, this method detects underlying regularities in herbal combinations, supporting the rational design of effective formulas. |
| Deep Learning and Imaging |  |  |
| Convolutional Neural Networks (CNNs) | Recognising visual patterns in molecular images can improve the chemical structure analysis of herbal compounds, facilitating drug discovery and compound function prediction. |
| Generative Adversarial Networks (GANs) | Used to generate personalised TCM prescriptions by learning from traditional prescription patterns and chemical data. |
| Knowledge Structuring and Transfer Learning |  |  |
| Representational Learning | Supports the construction of TCM knowledge graphs, improving the organisation, retrieval, and application of vast amounts of TCM data. |
| Transfer Learning | Enhances the identification and classification of herbs by applying learned patterns from related tasks to new, data-sparse environments. |
| Language and Text-Based Models |  |  |
| Natural Language Processing (NLP) and Generative Pretrained Transformers (GPT) | Extract pharmacological and chemical insights from classical texts and modern TCM literature, transforming unstructured textual knowledge into machine-readable formats for AI analysis. |
| Personalised Medicine and Clinical Decision Support |  |  |
| Transformer-Based Models and Deep Cross Neural Networks | Handle large patient datasets to generate tailored treatment strategies and optimise prescription planning—pioneering more precise and responsive inpatient care in TCM. |

These advanced technologies collectively facilitate a paradigm shift in Traditional Chinese Medicine—from empirical, experience-based practices toward more standardised, data-driven, and personalised approaches. By aligning ancient wisdom with modern scientific standards, AI empowers TCM to become more precise, reproducible, and adaptable to contemporary clinical and research environments.

## Chapter 3: Innovative AI Models and Techniques in TCM Research

A new generation of artificial intelligence models is reshaping the landscape of Traditional Chinese Medicine (TCM) by enabling more accurate, personalised, and evidence-informed approaches to diagnosis, treatment, and research. These technologies support a shift from intuition-based practice to data-enhanced decision-making, while respecting the holistic principles that underpin TCM. A range of AI models and techniques are enacted in TCM research. These include:

* **Graph Attention Networks (GATs):** GATS apply attention mechanisms to graph-structured data, allowing AI to focus on the most relevant features when analysing herb-compound interactions. In TCM, GATs recommend herbs based on their therapeutic relationships and synergistic effects, enabling more precise and personalised herbal prescriptions.
* **Representation Learning:** Representation learning is fundamental to building TCM knowledge graphs. It transforms complex clinical and pharmacological data into structured, machine-readable formats, facilitating improved information retrieval, pattern recognition, and the construction of intelligent decision-support systems in TCM.
* **Generative Adversarial Networks (GANs):** GANs consist of two competing neural networks—a generator and a discriminator—that produce new, realistic data. In TCM, GANs are used to generate customised herbal prescriptions by learning from large datasets of classical and clinical prescriptions, supporting the development of novel treatment plans tailored to individual patient needs.
* **Hybrid-Scale Graph Contrastive Learning:** Hybrid-scale graph contrastive learning is especially well-suited for TCM's holistic diagnostic framework, which integrates physical and psychological health indicators. This model uncovers latent patterns in TCM formulations by analysing the relationships among multiple herbs, diseases, and syndromes, aiding the discovery of clinically relevant herbal combinations and improving the understanding of TCM logic and formulation strategies.
* **Transformer-Based Models:** Transformers, originally designed for natural language processing, are now used in TCM for sequential data analysis, such as symptom progression and treatment history. These models are being implemented to recommend inpatient TCM prescriptions in hospital settings, improving the efficiency and consistency of clinical decision-making.
* **Deep Crossing Neural Networks:** Deep Crossing Networks are designed to process sparse and high-dimensional categorical data, such as patient demographics, symptom types, and TCM pattern classifications. By modelling the complex interactions among these variables, they generate more accurate and personalised prescription recommendations, improving clinical outcomes.

These advanced AI techniques strengthen the scientific foundation of Traditional Chinese Medicine and broaden its potential to meet the evolving demands of modern healthcare. By providing the computational tools to translate centuries of traditional knowledge into personalised, standardised, and globally applicable medical practices, AI enables TCM to thrive in an era of precision medicine.

## Chapter 4: The Evolution of AI in TCM

The integration of Artificial Intelligence (AI) into Traditional Chinese Medicine (TCM) has unfolded over several decades, reflecting both technological advancements and a growing interest in modernising ancient medical systems. From early rule-based systems to today’s deep learning models, the evolution of AI in TCM demonstrates a progressive attempt to bring precision, standardisation, and objectivity to traditional diagnostic methods.

**1950s–1970s: The Conceptual Foundations**

* **1950s**: Artificial Intelligence emerged as a field, with early research focusing on mimicking human problem-solving and decision-making. While these developments were largely theoretical, they laid the groundwork for applying AI principles across diverse domains, including healthcare.
* **1979**: The first computer program designed for TCM diagnosis was introduced. This marked the beginning of AI-assisted TCM diagnosis and the birth of intelligent systems within Chinese medicine.

**1980s: Rule-Based Expert Systems**

* The 1980s saw a surge in rule-based inference systems. These expert systems encoded diagnostic knowledge as a set of logical rules, mimicking the decision-making process of skilled TCM practitioners.
* In 1989, Professor Qin of Capital Medical University published *An Introduction to the Computer Simulation and Expert System of TCM*, which became a foundational work in the field. He categorised expert systems according to their cognitive and technical frameworks, providing a theoretical basis for further system development.

**1990s: Statistical Modelling and Early Intelligent Diagnostics**

* During the 1990s, mathematical inference models and statistical analysis began to supplement rule-based systems. These methods allowed for probabilistic reasoning, expanding the flexibility and applicability of AI in diagnosing complex TCM syndromes.
* Advances in pattern recognition and early machine learning techniques allowed for more adaptive systems, which moved beyond static rules and could learn from case data to improve diagnostic accuracy.

**2000s: Data Integration and Early Machine Learning**

* The 2000s marked a turning point, with increasing attention given to data integration. Digitisation of patient records, TCM literature, and clinical outcomes allowed for building databases to support knowledge-based systems.
* The field began experimenting with machine learning algorithms—including decision trees, support vector machines (SVMs), and early neural networks—to classify TCM syndromes better and analyse multi-dimensional patient data.
* Diagnostic imaging and digital tongue analysis tools began to emerge, setting the stage for objectified pattern recognition.

**2010s: Deep Learning, Mobile Health, and Smart Devices**

* The 2010s were defined by the rise of deep learning and the widespread adoption of mobile technologies. Convolutional Neural Networks (CNNs) were introduced for image-based analysis, including tongue and facial recognition aligned with TCM diagnostic principles.
* Wearable health technologies and smart pulse diagnostic devices emerged, integrating tactile sensors and data transmission systems that mimicked practitioner palpation.
* Research expanded in knowledge graphs, natural language processing (NLP), and multi-modal AI, allowing for greater integration of TCM text data, clinical cases, and unstructured patient records.

**2020s: Standardisation, Personalisation, and Clinical Integration**

* In the 2020s, the focus has shifted toward clinical application, personalisation, and global standardisation. AI platforms are now being developed to offer end-to-end diagnostic support—from symptom inquiry and image analysis to syndrome differentiation and treatment suggestions.
* Large-scale TCM databases are integrated with AI tools to improve pattern recognition and syndrome classification, especially for chronic and complex conditions.
* Applying transformer-based models (e.g., BERT, GPT) for TCM text interpretation and patient communication has enabled natural language understanding of symptoms and patterns unique to TCM.
* Global initiatives promote standardised frameworks (e.g., through ISO and WHO) to ensure the safe and effective use of AI tools in TCM practice across different healthcare systems.
* Chinmedomics—the study of TCM's chemical and molecular mechanisms—is also growing. AI maps bioactive compounds to treatment outcomes, thus supporting personalised herbal prescriptions.

From early rule-based expert systems to today's AI-powered diagnostic platforms, the application of Artificial Intelligence in TCM continues to evolve, bridging traditional wisdom with technological innovation. As TCM embraces standardisation, digitisation, and intelligent transformation, AI will play an increasingly vital role in globalising its practices and improving diagnostic precision, treatment personalisation, and patient care outcomes.

# PART 1: AI-Assisted Diagnostics

Traditional Chinese Medicine (TCM) diagnosis is grounded in a holistic worldview that sees the human body as an integrated system of physical, emotional, and energetic functions constantly interacting with the environment. Rather than isolating symptoms or relying solely on molecular markers and physiological indicators, TCM aims to assess the totality of an individual’s health, considering both internal imbalances and external influences. Diagnosis is not about identifying a disease in isolation but about understanding patterns of disharmony and their root causes to guide personalised and dynamic treatment strategies. Central to this diagnostic framework are the Four Diagnostic Methods:

1. **Inspection (望, Wàng):** Visual observation of the patient’s physical appearance, including complexion, posture, body shape, and tongue characteristics. This provides key indicators of internal organ function and systemic balance.
2. **Auscultation and Olfaction (闻, Wén):** Listening to the quality of the voice, breathing, and cough, and detecting odours from the body or breath to gather insights into internal pathologies.
3. **Inquiry (问, Wèn):** A comprehensive patient interview covering physical symptoms, emotional states, sleep, digestion, energy levels, menstruation (if applicable), diet, lifestyle, and medical history. This helps contextualise the observed symptoms and detect deeper imbalances.
4. **Palpation (切, Qiè):** Primarily pulse diagnosis, where practitioners feel the radial artery at three positions on each wrist (cun, guan, chi) and at varying depths to assess the condition of internal organs and energetic flow.

These diagnostic approaches allow the practitioner to identify *patterns* (or “syndromes”) rather than merely diagnose diseases. Each pattern reflects a specific constellation of signs and symptoms that point to underlying disharmonies in Qi, Blood, Yin-Yang balance, or organ function.

With the rise of Artificial Intelligence (AI), TCM is entering a new era where traditional methods are being digitised, standardised, and enhanced through cutting-edge technology. AI provides a promising pathway to overcome some of the historical challenges of TCM diagnostics, such as subjectivity, practitioner variability, and the lack of standardisation, by applying advanced sensors, machine learning algorithms, and data analytics to replicate and expand upon traditional diagnostic techniques. AI-assisted diagnostic systems now employ tools such as:

* High-resolution imaging and computer vision to perform detailed tongue and facial analysis.
* Tactile sensors that simulate fingertip pressure to analyse pulse waveforms
* Natural language processing (NLP) to interpret patient inquiry data.
* Olfactory sensors and sound analysis to assist with smell and voice diagnostics.
* Multimodal data integration platforms that consolidate inputs from inspection, palpation, inquiry, and auscultation into unified diagnostic models

By training algorithms on large, annotated datasets—including clinical records, syndrome patterns, and treatment outcomes—AI systems can identify subtle patterns across different patients, enhancing both the objectivity and precision of diagnosis. This has major implications for clinical practice, education, research, and global standardisation of TCM.

AI-assisted diagnosis does not replace the wisdom and insight of experienced TCM practitioners—it augments their capabilities. The synergy between ancient holistic principles and modern data science opens a path toward more personalised, efficient, and globally accessible healthcare. As TCM continues to modernise, AI offers a transformative tool for reinforcing its credibility, refining its practices, and expanding its relevance in today’s evidence-based medical landscape.

## Chapter 5: AI Pulse Diagnosis

In Traditional Chinese Medicine (TCM), the pulse (*mo*) is regarded as one of the most important and sophisticated diagnostic techniques. It offers profound insights into the state of the patient’s internal organs and the flow of essential substances such as Qi (vital energy), Xue (blood), and body fluids. Mastering pulse diagnosis requires deep theoretical knowledge, highly developed tactile sensitivity, and diagnostic intuition.

Traditionally, the pulse is examined at the radial artery on both wrists, with each wrist divided into three sections:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Section | Position | Cosmological Principle | Jiao | Organs |
| Cun (寸) | The most distal position, near the base of the thumb | Heaven | Linked to the Upper Jiao | Reflecting the head, heart, and lungs |
| Guan (关) | The middle position | Man | Associated with the Middle Jiao | Reflecting the stomach, spleen, and liver |
| Chi (尺) | The proximal position, closest to the elbow | Earth | Corresponding to the Lower Jiao | Governs the kidneys, bladder, and reproductive organs |

Each of these three positions is palpated at three depths, which correspond to different physiological layers: the superficial level reflects Yang aspects and the condition of Qi, the intermediate level provides insight into blood and functional organ activity, and the deep level corresponds to Yin aspects, such as constitutional strength and the state of the Zang organs. These positions are further associated with the Three Burners (San Jiao) and cosmological principles.

Because of its complexity and subjectivity, pulse diagnosis demands years of hands-on training and clinical experience. Factors such as pulse depth, speed, strength, rhythm, width, and tension are evaluated simultaneously to identify one or more of the 28 traditional pulse types, each associated with specific patterns of disharmony.

### Arterial Pulse Waveform

To modernise and standardise pulse diagnosis in Traditional Chinese Medicine (TCM), researchers have increasingly turned to the study of arterial pulse waveforms. This approach aims to develop objective, quantifiable strategies that can reflect traditional diagnostic categories with scientific precision. In pursuit of this goal, a wide variety of sensors have been employed to detect and capture pulse signals, including:

* Piezoelectric sensors
* Piezoresistive strain gauges
* Magnetic and liquid sensors
* Acoustic and Doppler ultrasonic devices
* Infrared and optical photoelectric sensors

These technologies can translate tactile pulse sensations into digital waveforms, which can then be processed and analysed.

Once the pulse signal is acquired, it undergoes a series of computational steps to extract meaningful diagnostic information. Key waveform parameters include:

* Wavelength
* Relative phase difference
* Rate parameters
* Peak ratios

The relative variation between these indices serves as a basis for distinguishing between different pulse types, such as wiry, slippery, thready, or rapid, each associated with specific TCM syndromes. Researchers have begun integrating artificial intelligence (AI) techniques, particularly neural networks, to enhance diagnostic accuracy further and classify pulse patterns. Training these models on annotated pulse waveform datasets makes it possible to automatically recognise subtle distinctions between pulse qualities, thereby reducing practitioner subjectivity and advancing the goal of a standardised, objective pulse diagnosis system.

### Tactile Array and Pulse Sensors

Tactile array technologies and pulse sensors have been successfully applied to detect specific arterial pulse characteristics, offering a more objective and replicable approach to Traditional Chinese Medicine (TCM) pulse diagnosis. Among the most advanced systems developed is the Bi-Sensing Pulse Diagnosis Instrument, which integrates a Pressure Displacement Bi-Sensing System with a robotic finger equipped with extremely sensitive pressure sensors.

These sensors are designed to simulate the tactile sensations of a TCM practitioner’s fingertips, capturing subtle variations in pulse depth, strength, and rhythm. The robotic fingers apply consistent, calibrated pressure across the wrist's Cun, Guan, and Chi positions, producing high-resolution pulse waveforms.

Studies have shown that the pulse signals acquired from these robotic systems closely match the diagnostic impressions of skilled TCM practitioners, demonstrating their potential as effective tools for standardising pulse diagnosis and supporting clinical decision-making. By combining tactile sensing with AI-driven pattern recognition, these technologies pave the way for more consistent, accessible, and scientifically validated TCM diagnostics.

### Pulse Measurement Devices

Pulse measurement devices represent a convergence of Traditional Chinese Medicine (TCM) diagnostic principles and modern technological advancements. These devices aim to enhance diagnostic accuracy, support personalised treatment plans, and improve patient engagement by making TCM pulse diagnosis more objective, measurable, and accessible. Options available on the pulse measurement device market include:

|  |  |  |
| --- | --- | --- |
| Device | Overview | Use Cases |
| [**Nadifit® Pulse Diagnosis Device**](https://nadifithub.com/) | Combines AI-driven analysis with TCM and Ayurvedic principles to provide comprehensive health assessments. It evaluates organ energy levels, identifies root causes of health issues, offers diet and lifestyle recommendations based on pulse analysis, and generates detailed health reports with visualisations for better patient understanding. | Ideal for clinics aiming to enhance diagnostic accuracy and patient engagement. |
| [**Nadiswara Pulse Diagnosis Device**](https://nadiswara.com/) | An AI-powered device that blends ancient Ayurvedic wisdom with modern technology for precise health insights. It conducts comprehensive pulse readings in just 30 seconds, provides detailed reports on dosha balance, digestion efficiency, and organ energy levels and syncs with a dedicated mobile application for patient record management and progress tracking. | Suitable for healthcare professionals, educational institutions, and wellness centres. |
| [**VedaPulse®**](https://vedapulse.com/portal/) | A multifunctional hardware and software complex designed for practitioners of traditional healing systems, including TCM. It evaluates functional health states using heart rate variability (HRV) analysis, creates personalised rehabilitation programs based on TCM principles, and offers modules for diet therapy, herbal recommendations, and more. | Beneficial for practitioners seeking a comprehensive tool for health assessment and personalised treatment planning |
| [**Wearable Combined Wrist Pulse Measurement System**](https://www.mdpi.com/1424-8220/19/2/386) | A wearable device that uses airbags for pressurisation to collect pulse data, aligning with TCM diagnostic methods. It adjusts to locate Cun, Guan, and Chi regions on the wrist, captures pulse waveforms under varying pressures for comprehensive analysis and is suitable for home, medical, and experimental research applications. | Ideal for researchers and practitioners interested in objective pulse data collection. |
| [**Bionic Pulse Diagnosis Equipment**](https://link.springer.com/article/10.1007/s43657-023-00104-2) | A digital protocol for TCM pulse information collection using bionic equipment to ensure high efficiency and data integrity. It simulates traditional pulse-taking methods with robotic precision, generates rich pulse information, including multi-gradient dynamic pulse force time series and facilitates the standardisation of digitalised pulse information collection. | Suitable for fundamental and clinical research in TCM pulse phenomics. |

To overcome the inherent variability of traditional pulse readings, AI algorithms are employed to preprocess pulse data, including filtering, denoising, and normalisation, to ensure signal clarity and consistency. These preprocessing steps are critical for transforming raw tactile signals into data suitable for accurate interpretation and classification.

One of the current challenges in the field is the lack of cross-device compatibility. Different pulse measurement devices, developed by various manufacturers, may vary in sensor type, data format, and sensitivity. AI technologies are now designed to enhance interoperability, allowing algorithms to interpret data consistently across multiple platforms. This effort is key to achieving data standardisation for clinical reliability and large-scale adoption. However, AI-driven pulse diagnosis in TCM still faces limitations due to the absence of universally accepted diagnostic standards and the slow development of robust, standardised measurement devices. Without uniform benchmarks for pulse characteristics and diagnostic criteria, validating and scaling these technologies in clinical settings is difficult.

To address these gaps, the future development of pulse measurement systems must focus on establishing unified pulse data protocols, promoting inter-device data compatibility, and integrating multiple diagnostic modalities (e.g., tongue, facial analysis, and pulse) into comprehensive AI platforms and conducting clinical validation studies to align machine-generated insights with practitioner expertise.

### The Quantification of Pulse Diagnosis

The quantification of pulse patterns is critical in transforming Traditional Chinese Medicine (TCM) pulse diagnosis from a subjective art into a standardised, evidence-based clinical tool. Traditionally, pulse diagnosis depends on a practitioner’s tactile sensitivity and interpretive skill to distinguish between complex pulse types, such as wiry, slippery, thready, or deep pulses, each corresponding to distinct internal conditions. However, this process is inherently subjective, lacking consistent parameters or measurable data that can be reliably shared, reproduced, or validated across practitioners and settings.

AI-directed pulse diagnosis focuses on systematically quantifying pulse signals through high-resolution sensors and advanced data analytics to address this limitation. These systems capture and digitise arterial pulse waveforms, enabling the extraction of a wide range of quantifiable features, including:

* Amplitude and intensity
* Pulse waveform shape.
* Wavelength and frequency
* Peak intervals and ratios
* Phase differences
* Pulse depth and duration.
* Rate variability and rhythm regularity.

Once these variables are extracted, AI algorithms—particularly deep learning models such as convolutional neural networks (CNNs) or recurrent neural networks (RNNs)—are trained on labelled datasets to recognise and classify patterns corresponding to traditional TCM pulse types. These models can emulate practitioner interpretation while reducing human error and bias.

Quantification also allows for data consistency across different devices and users, longitudinal monitoring of patient conditions, comparative studies across populations, treatment protocols, and geographic regions and multimodal integration with other diagnostic streams (e.g., tongue and face analysis) for holistic syndrome differentiation. However, realising the full potential of AI-directed pulse diagnosis requires the development of standardised diagnostic criteria and uniform data acquisition protocols. Without agreed-upon definitions for pulse features or benchmark datasets, there is a risk of fragmentation and inconsistent clinical outcomes. Thus, ongoing research efforts are focused on establishing universal pulse feature taxonomies, creating large-scale, annotated datasets based on practitioner-labelled cases, enhancing signal fidelity and sensor resolution and integrating AI models into user-friendly platforms for clinical and home-based applications.

Quantifying pulse patterns through AI enhances diagnostic precision and lays the groundwork for the scientific modernisation of TCM. As AI continues to evolve, its role in standardising and scaling pulse diagnosis will be central to building trustworthy, data-driven, and globally accessible TCM diagnostic systems.

## Chapter 6: AI Tongue Analysis

In Traditional Chinese Medicine (TCM), tongue diagnosis is a foundational diagnostic technique used to assess the state of the internal organs and the flow of the body’s fundamental substances—Qi (vital energy), Xue (blood), and Jin-ye (body fluids). The tongue is regarded as a mirror of the internal body, reflecting both physiological balance and pathological disturbances. Practitioners observe a range of tongue features to gather diagnostic clues, including:

* Colour (e.g., pale, red, purple)
* Size and shape (e.g., swollen, thin, scalloped edges)
* Coating (e.g., thick, thin, white, yellow)
* Moisture, texture, movement, and the presence of cracks or teeth marks

Each area of the tongue corresponds to specific organ systems—for example, the tip reflects the Heart and Lung, the sides represent the Liver and Gallbladder, the centre is linked to the Spleen and Stomach, and the root corresponds to the Kidneys and Bladder. Despite its value, tongue diagnosis is inherently subjective, relying heavily on the practitioner's experience, training, perceptual skill, and consistent lighting and viewing conditions. These challenges make standardising or replicating diagnostic outcomes difficult, creating a natural opening for technological intervention.

This growing need for objectivity and consistency has led to the emergence of AI-assisted tongue diagnosis systems, which aim to automate the analysis of tongue features using computer vision, image processing, and machine learning. The following section explores the current landscape of these technologies, including key apps and platforms, their capabilities, and the challenges they aim to overcome.

### The Automatic Tongue System (ATDS)

With the rapid evolution of artificial intelligence and computer vision, automatic tongue reading systems are beginning to reshape Traditional Chinese Medicine (TCM) diagnoses. These systems aim to automate the interpretation of tongue features by detecting patterns associated with internal imbalances in Qi, blood, and organ systems, making the diagnostic process more consistent, accessible, and potentially more accurate. The Automatic Tongue System is a computer-aided tool that interprets digital images of the tongue according to established TCM principles. It assesses key visual elements—such as colour, coating, moisture, shape, and texture—and uses machine learning algorithms to relate these features to specific TCM syndromes. Central to this system are convolutional neural networks (CNNs), which enable the AI to process complex visual data with growing precision.

Despite being a relatively young field, several AI-powered tongue diagnosis systems and apps are already available or under development, each with varying levels of sophistication and clinical relevance. Below are a few notable examples:

|  |  |  |
| --- | --- | --- |
| Platform | Function | Features |
| [**iTongue**](https://itongue.cn/) **(China)** | Offers AI-assisted tongue diagnosis via smartphone image uploads. It analyses tongue colour, shape, coating, and texture to suggest possible TCM syndromes. | * User-friendly for non-practitioners * Visual feedback and health suggestions * Includes basic lifestyle guidance based on TCM patterns. |
| [**Tongue Wisdom (MyZenCheck**](https://myzencheck.com/)**, Singapore)** | Uses AI and computer vision to analyse tongue images and generate health reports based on TCM diagnosis models. | * Incorporates Microsoft Azure’s medical AI engine. * Offers personalised wellness advice. * Encrypted data handling for privacy |
| [**QiHealth Tongue Diagnostic Tool**](https://www.qihealth.io/get-started) | Provides free tongue image analysis through a guided upload process, producing a visual diagnostic map with interpretations tied to TCM principles. | * Identifies patterns like Yin deficiency or Damp-Heat * Uses segmentation and colour processing. * Provides recommendations for dietary or lifestyle changes |
| [**TongueMobile**](https://pmc.ncbi.nlm.nih.gov/articles/PMC11526409/) **(Research Prototype)** | TongueMobile is a mobile application designed for the general public to perform tongue diagnosis using their smartphones. The app captures tongue images, segments the tongue body using Mask R-CNN, and classifies the tongue coating colour using deep learning models. | * High-level image segmentation * Designed to detect tongue body features and coating under varied conditions. * Built for training and testing AI tongue models |
| **BianQue AI System (China Academy of TCM)** | Integrates AI for the "Four Diagnostic Methods"—including tongue inspection—as part of a holistic TCM diagnostic tool | * Used in research hospitals and TCM universities. * Advanced image processing paired with pulse and facial analysis. * Aims to standardise digital diagnosis across clinical settings |
| **Deep Learning-Based Automated Tongue Analysis System** | This system combines deep learning with TCM to enhance the accuracy and objectivity of tongue diagnosis. It includes a hardware device for stable image acquisition, a semi-supervised learning segmentation algorithm based on U2Net, a high-performance colour correction module, and a tongue image analysis algorithm that fuses different features according to the characteristics of each TCM tongue image | |
| [**Intelligent Tongue Diagnosis System via Deep Learning on Smartphones**](https://www.mdpi.com/2075-4418/12/10/2451?utm_source=chatgpt.com) | This system integrates tongue detection, segmentation, and classification models into a smartphone application. It allows users to capture tongue images, which are then processed to provide diagnostic reports and treatment recommendations based on TCM principles. | |
| [**Dr. Tongue: Sign-Oriented Multi-Label Detection for Remote Tongue Diagnosis**](https://arxiv.org/abs/2501.03053?utm_source=chatgpt.com) | Dr. Tongue is a framework designed for remote medical assessments, especially pertinent during the COVID-19 pandemic. It utilizes a Sign-Oriented Network (SignNet) to identify specific tongue attributes, emulating the diagnostic process of experienced practitioners. | |
| [**TongueSAM: A Universal Tongue Segmentation Model Based on SAM with Zero-Shot Learning**](https://arxiv.org/abs/2308.06444?utm_source=chatgpt.com) | TongueSAM leverages the Segment Anything Model (SAM) to perform zero-shot tongue segmentation, enabling it to handle diverse tongue images without the need for extensive labelled datasets. | |

Despite growing interest and promising developments, current tongue reading systems face several technical and practical limitations. As Matos et al. (2021) point out, several barriers still need to be addressed before these systems can be fully standardised and widely trusted. Among the most pressing challenges are:

* **Environmental lighting conditions**: Variations in ambient light significantly affect image consistency. Reliable diagnosis requires controlled or standardised lighting, ideally using artificial illumination with stable temperature and intensity.
* **Low image resolution**: Many mobile-based systems use standard smartphone cameras, often lacking the resolution to capture fine tongue features. This limits the accuracy of visual assessments, particularly for small signs like cracks, red spots, or subtle coating changes.
* **Lack of colour correction**: Without calibrated colour systems, it becomes difficult to determine whether a tongue’s hue reflects a true physiological state or results from lighting distortion or device bias.
* **Weak correlation with clinical diagnosis**: Many apps on the market currently lack robust links between their AI-generated outputs and established TCM diagnostic criteria. Until stronger clinical validation is achieved, these tools must be considered supplementary rather than definitive.

Still, the field is moving forward. Further research into AI-assisted tongue diagnostics is expected to resolve many of these issues, particularly as datasets grow in quality and diversity and image capture methods become more controlled. Addressing these design flaws, especially around imaging conditions, diagnostic accuracy, and integration with practitioner-based decision-making, will be crucial to building technically reliable and clinically meaningful systems.

Ultimately, while the Automatic Tongue System is still in development, its potential to reduce subjectivity, improve accessibility, and contribute to the standardisation of TCM practice is significant. As researchers refine the technology, these systems may soon become a trusted part of professional diagnostics and digital self-care.

### AI-Analysed Tongue Reading

Enhanced by artificial intelligence and computer vision advancements, AI-analysed tongue diagnosis is revolutionising one of Traditional Chinese Medicine’s (TCM) most ancient and intuitive diagnostic techniques. By automating the interpretation of tongue features, these systems help identify patterns that correlate with internal imbalances in Qi, blood, and organ systems, thus supporting practitioners with faster, more standardised assessments. AI-analysed tongue reading is a computer-aided diagnostic system that interprets tongue images using TCM diagnostic principles. The system uses machine learning algorithms—particularly convolutional neural networks (CNNs)—to assess key visual features and map them to recognised TCM syndromes. The Five Phases of AI-analysed tongue reading include:

1. **Image Capture**: The process begins with the user or patient taking a high-resolution image of their tongue using a smartphone or specialised diagnostic device. To ensure diagnostic reliability, guidelines are followed for lighting (preferably standardised or natural white light), angle (tongue flat, fully extended), tongue position and background (neutral, non-reflective)
2. **Image Preprocessing**: Before analysis, the image undergoes preprocessing to enhance clarity and isolate relevant regions background removal and noise reduction lighting correction and colour normalisation and the segmentation of the tongue into standard diagnostic zones (e.g. tip (Heart), sides (Liver and Gallbladder), centre (Spleen and Stomach) and root (Kidney, Bladder, Intestines))
3. **Feature Assessment:** The AI uses trained computer vision algorithms to evaluate the tongue’s surface for features significant in TCM. These may include:

|  |  |
| --- | --- |
| Feature | TCM Significance |
| Colour | Pale (Qi/Blood deficiency), Red (Heat), Purple (Stasis) |
| Coating | Thick (Damp/Phlegm), Yellow (Heat), White (Cold) |
| Moisture | Dry (Yin deficiency), Wet (Damp/Cold) |
| Shape | Swollen (Damp/Spleen Xu), Thin (Yin or Blood Xu) |
| Scalloped Edges | Spleen Qi deficiency |
| Cracks | Heat or Yin deficiency |
| Red Dots | Heat or Inflammation |

1. **Pattern Matching**: Once features are extracted, the system compares them to a library of labelled images and diagnostic case data. The AI then matches the user’s tongue characteristics to known TCM syndrome patterns such as Spleen Qi Deficiency with Damp, Liver Fire Rising, Heart Yin Deficiency or Blood Stagnation with Internal Cold
2. **Diagnostic Report Generation:** The final phase is the creation of a comprehensive diagnostic report, which may include a summary diagnosis (e.g., “Mild Qi and Blood Deficiency with Damp Accumulation”), a tongue map highlighting affected zones and linked organ systems, tailored recommendations based on the syndrome identified:, suggestions for herbal formulas, acupuncture points, dietary and lifestyle modifications and a prompt to consult with a licensed TCM practitioner for deeper evaluation

AI-assisted tongue reading systems promise to transform TCM diagnosis by introducing objectivity, reproducibility, and standardisation. By training these algorithms on large, diverse datasets—with expert-annotated labels and diagnostic histories—AI can detect subtle visual patterns that may elude the human eye. Over time, these systems will evolve to reduce practitioner subjectivity, improve diagnostic accuracy across varied populations, enable early detection of imbalances and integrate with telemedicine platforms for remote diagnosis and self-care.

Although challenges remain—particularly in achieving standardised image conditions, colour calibration, and clinical validation—the pathway toward reliable AI-driven tongue diagnosis is becoming increasingly clear. As Matos et al. (2021) noted, improvements in imaging technology combined with advanced data processing will contribute significantly to overcoming current limitations and accelerating the modernisation of tongue diagnosis in clinical practice.

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### Tongue Reading Apps

The rapid advancement of smartphone technology has opened new possibilities for immediate and accessible diagnostic tools in Traditional Chinese Medicine (TCM). Among these innovations, tongue reading apps have emerged as a growing area of interest, aiming to digitise and democratise one of TCM’s core diagnostic methods. These applications typically use a smartphone camera to capture images of the tongue, which are then analysed—either manually or via AI algorithms—to infer underlying imbalances or syndromes.

Several tongue diagnosis apps are available on the market, offering various features and differing levels of accuracy, objectivity, and clinical relevance. Some rely on manual input and simple symptom mapping, while others integrate advanced image processing and artificial intelligence to assess the tongue’s shape, colour, coating, and texture in real time. These tools hold promise for self-monitoring, preventive care, and remote consultations, potentially extending the reach of TCM to broader populations. Tongue reading apps on the market include:

|  |  |
| --- | --- |
| App | Description |
| Tongue Wisdom by MyZenCheck | * AI-powered tongue diagnosis using Microsoft’s Custom Vision and Azure Medical AI Agent. * Provides personalised health reports based on TCM principles. * Secure data encryption and progress tracking. |
| iTongue | * Analyses tongue images to offer food and lifestyle advice based on TCM. * Includes a questionnaire for additional health assessment. * Provides warnings about potential physical and mental weaknesses. |
| Tongue Diagnosis by Nguyen Tran | * Educational tool for TCM students and practitioners. * Includes quizzes and summary theories for quick review. * Offline access with structured, academic references. |
| Qi Health | * Offers free tongue diagnosis with holistic treatment recommendations. * Analyses tongue's colour, coating, shape, moisture, and texture. * Provides insights into overall health and potential imbalances. |
| TongueMobile | * Automated tongue segmentation and diagnosis using deep learning. * Utilises Mask R-CNN for image segmentation and ResNeXt for coating colour classification. * Provides users with segmented images and diagnosis results. |

However, significant technical and clinical challenges remain despite the enthusiasm surrounding these tools. As Matos et al. (2021) highlight, many current tongue-reading apps face limitations that hinder diagnostic reliability and clinical adoption. These include:

* Variability in environmental lighting conditions, which affects colour perception and consistency.
* There is a lack of standardised artificial illumination with controlled temperature for image capture.
* Low image resolution on some devices reduces the ability to detect fine details critical to diagnosis.
* The absence of reliable colour correction algorithms leads to hue and coating analysis inaccuracies.
* A weak or inconsistent correlation between app-generated results and established clinical diagnoses, reducing trust among practitioners.

These challenges highlight the need for further research and development in AI-assisted tongue diagnostics. Key areas of focus include the creation of standardised imaging protocols, improving colour and texture calibration techniques, and integrating validated diagnostic models. Furthermore, training AI systems on large, diverse datasets—paired with expert-verified annotations—will be essential for improving diagnostic precision and building clinical credibility. Future Directions include:

* **Development of smartphone attachments** or controlled-light environments to improve image consistency.
* **Cross-platform data harmonisation** to ensure reproducibility across devices.
* **Incorporation of user-friendly interfaces** that guide proper image capture and flag poor image quality.
* **Clinical validation studies** to align AI interpretations with practitioner insights and patient outcomes.

Tongue-reading apps represent a significant step forward in the digital transformation of TCM diagnostics. While current offerings show promise, they remain limited by technical constraints and a lack of clinical standardisation. Ongoing research, improved design standards, and robust AI training will be crucial to overcoming these limitations. As technology matures, these apps may evolve into highly accurate, accessible, and clinically accepted tools, bridging traditional wisdom with modern healthcare delivery.

### The Future of Tongue Reading

The future of AI in Traditional Chinese Medicine (TCM) holds transformative potential, particularly in tongue diagnosis, one of the oldest and most visually rich diagnostic tools in TCM. As research and technology advance, AI is poised to reinterpret this traditional practice through highly sophisticated and objective methodologies. One of the most promising directions is the development of AI algorithms capable of analysing tongue features, such as shape, colour, coating, moisture, and fissures, with consistency and precision that surpasses human perception. By training machine learning models on large, high-quality image datasets, researchers aim to uncover subtle patterns and diagnostic markers that may not be easily discernible by even the most experienced clinicians.

While this goal has not yet been fully realised, the integration of cutting-edge image recognition systems, computer vision, and deep learning techniques makes the standardisation of tongue diagnosis increasingly feasible. Matos et al. (2021) suggest that advancements in imaging systems, combined with robust data analytics, offer a clear pathway to creating objective, reproducible, and quantifiable tongue assessments. These technological strides could eventually lead to the parameterisation of visual indicators, laying the groundwork for digital tongue analysis to be accepted in clinical and research settings globally. Key Innovations on the Horizon include:

* **High-Resolution Imaging Systems**: Enhanced optical and spectral imaging can capture nuanced tongue features under standardised conditions, improving accuracy across different lighting and skin tones.
* **AI-Powered Diagnostic Engines**: Deep learning models trained on large-scale, annotated tongue image databases can link visual characteristics to syndromes, organ imbalances, and disease risk with growing accuracy.
* **Mobile Tongue Scanning Tools**: With the rise of smartphones and health apps, portable AI-driven tongue reading systems can empower self-assessment and remote consultations, expanding TCM access.
* **Multimodal Integration**: Combining tongue analysis with facial recognition, voice analysis, and pulse data may lead to holistic AI diagnostics that reflect the full spectrum of TCM’s four traditional methods.

The implications are vast. AI could help standardise tongue reading, reducing practitioner subjectivity and regional variation. It may also play a role in early disease detection, where minute changes in the tongue's appearance—imperceptible to the naked eye—could signal developing imbalances. In research contexts, AI could help validate TCM syndromes and establish stronger correlations between tongue features and biomedical markers.

Despite this promise, challenges remain. Standardising tongue image capture across devices, defining universal diagnostic criteria, and ensuring models generalise across populations are ongoing hurdles. Moreover, ethical concerns about data privacy and medical liability must be addressed as AI takes on more diagnostic responsibility.

The future of tongue reading lies in a fusion of ancient wisdom and advanced analytics. As AI technologies evolve, tongue diagnosis may shift from a primarily intuitive art to a rigorous, data-driven science, enhancing clinical outcomes, advancing TCM research, and promoting its integration with global health systems. With continued interdisciplinary collaboration, what once seemed a subjective craft may soon become a cornerstone of AI-enhanced precision medicine.

## Chapter 7: AI Face Reading

Face reading, also known as *mien shiang* (面相), is an ancient diagnostic method in Traditional Chinese Medicine (TCM) that involves observing a person’s facial features to assess their health, temperament, and internal organ function. Based on the principle that the face reflects the body's internal state, this practice interprets subtle skin tone, texture, shape, and expression cues to detect physiological and pathological changes. In TCM, different regions of the face correspond to different internal organs:

* **Forehead**: Heart and Small Intestine
* **Eyebrows and temples**: Liver and Gallbladder
* **Nose**: Spleen and Stomach
* **Cheeks**: Lungs
* **Chin and jaw**: Kidneys and Bladder
* **Eyes and surrounding area**: Overall vitality, Shen (spirit), and blood quality

Practitioners examine a range of features, including complexion and colour tone (e.g., red, pale, greenish tint), skin texture and moisture, lines, swelling, puffiness, or sagging, asymmetry, tension, or hollowing and emotional expression and the brightness or dullness of the eyes. Face reading is particularly valued for its ability to detect latent imbalances that may not yet have manifested as physical symptoms. Like tongue and pulse diagnosis, however, it depends heavily on the practitioner’s experience, observational skill, and intuition. It can be affected by external variables such as lighting, stress, or cosmetic alterations.

### AI and the Evolution of TCM Face Reading

Integrating artificial intelligence (AI) and computer vision into face reading rapidly redefines the field, offering a path to standardisation, precision, and widespread accessibility. AI-assisted face reading uses image recognition algorithms trained on thousands of annotated facial images to detect and interpret features linked to TCM diagnostic principles. Key developments include:

* **Facial zone mapping**: Segmenting the face into organ-related regions for detailed analysis.
* **Skin tone and hue analysis**: Objectively measuring subtle colour changes associated with blood flow, Qi stagnation, or organ deficiency.
* **3D facial modelling**: Capturing fine details such as puffiness, hollowness, swelling, and symmetry changes from multiple angles.
* **Emotion and Shen recognition**: Analysing micro-expressions and eye brightness to evaluate emotional and spiritual well-being (Shen).

Advanced systems are beginning to link these facial indicators to **personalised diagnostic suggestions**, TCM syndromes, or lifestyle recommendations. These AI models often work with other diagnostic tools (e.g., tongue analysis, pulse sensors), creating a **multimodal diagnostic ecosystem** that mirrors TCM's holistic nature.

### The Future of Face Reading

AI has the potential to revolutionise TCM face reading in several important ways:

* **Standardisation**: Removes practitioner bias and variability using measurable, reproducible image data.
* **Accessibility**: Makes facial diagnostics available through smartphone apps or telehealth platforms, expanding reach to rural or underserved areas.
* **Preventive health**: It enables the early detection of internal imbalances through subtle facial signs, supporting a shift from reactive to preventive care.
* **Education and training**: Provides guided, data-driven feedback to assist TCM students and new practitioners in learning face reading.
* **Integration with digital health**: Face reading has the potential to be included in comprehensive AI wellness platforms alongside heart rate variability, pulse diagnosis, and biometric monitoring.

However, challenges remain, including the need for large, ethnically diverse datasets, standardised image capture protocols, and clinical validation of AI-generated assessments. Additionally, preserving the human element of Shen observation—a practitioner has felt sense of the spirit or vitality of the patient—remains a unique and irreplaceable aspect of TCM face reading.

AI is not replacing face reading in TCM but refining and expanding its potential. By combining ancient diagnostic wisdom with the analytical power of modern technology, AI-assisted face reading may soon become a valuable tool in professional practice and personalised wellness. As this field matures, it promises to honour the depth of TCM traditions while ushering in a new era of data-driven, accessible, and preventative medicine.

## Chapter 8: AI and Syndrome Differentiation

Syndrome differentiation (辨证论治, *bian zheng lun zhi*) lies at the heart of Traditional Chinese Medicine (TCM). It is the central diagnostic principle through which practitioners analyse symptoms, tongue and pulse features, and constitution to determine a patient’s syndrome—an integrated picture of physiological and pathological changes. Syndrome differentiation distinguishes between diseases (病, bing) and the syndromes (证, *zheng*) that reflect the patient's internal imbalances in *Qi*, *blood*, *Yin-Yang*, and organ function. The process is inherently holistic and interpretive, requiring years of clinical training. However, it can be highly subjective and variable between practitioners. Artificial Intelligence (AI) offers a breakthrough opportunity to bring greater accuracy, consistency, and objectivity to syndrome differentiation by analysing large, complex datasets that traditional methods cannot easily process.

Modern AI models—particularly Bidirectional Long Short-Term Memory with Conditional Random Fields (BiLSTM-CRF) and Transformer architectures—are now being trained to emulate and enhance human reasoning in syndrome classification:

* BiLSTM-CRF models are well-suited to processing sequential patient data, such as symptom descriptions, case histories, and pulse/tongue image features. They can learn temporal dependencies and contextual relationships, improving classification accuracy overrule-based systems.
* Transformer models—especially those adapted from NLP tasks—excel at understanding complex patterns across large text and image datasets. They can simultaneously process multimodal information (e.g., symptoms + tongue + pulse), offering a comprehensive analysis of patient data.

These models are trained using annotated medical records and expert-labelled datasets, allowing them to learn the implicit logic of TCM diagnosis and provide exceptionally reliable syndrome predictions.

AI-enhanced syndrome differentiation directly impacts individualised treatment strategies, a foundational principle in TCM. With precise syndrome classification, AI can support practitioners in selecting the most appropriate herbs, acupuncture points, or therapeutic approaches. This is particularly valuable in chronic disease management and cancer care, where accurate syndrome diagnosis must be matched with herbal formulations tailored to the patient's internal environment.

Some systems go a step further by linking syndrome patterns to chemical composition data of herbs and patient biomarkers. This enables AI to recommend herbal prescriptions based on energetic and biochemical compatibility, bridging the gap between traditional theory and modern pharmacological insight. Integrating AI into syndrome differentiation offers several important benefits:

* **Standardisation**: Reduces diagnostic variability across practitioners and institutions
* **Efficiency**: Shortens the time required for complex diagnostic reasoning
* **Clinical Support**: Offers second opinions or confirmations to assist less experienced clinicians.
* **Scalability**: Makes TCM diagnostic logic accessible in remote or underserved areas via mobile platforms
* **Research Advancement**: Supports retrospective analysis, syndrome pattern discovery, and integration with Western medical data.

AI-driven syndrome differentiation represents a critical frontier in modernising Traditional Chinese Medicine. By enhancing the accuracy and objectivity of core diagnostic processes, AI supports clinicians in delivering personalised care and reinforces TCM's scientific foundation. As AI models become more sophisticated and datasets more comprehensive, we are moving toward a future where ancient diagnostic wisdom is augmented by powerful computational tools, opening new pathways for integrative, precise, and globally credible TCM practice.

## Chapter 8: The Future of Data Collection

As Traditional Chinese Medicine (TCM) enters the digital age, data collection and interpretation are becoming increasingly central to clinical care and research. AI technologies, particularly deep learning and neural networks, are poised to revolutionise how data is gathered, processed, and applied within the TCM framework. AI excels at interpreting complex, multi-layered information typically collected during a TCM consultation—including symptoms, tongue and pulse observations, lifestyle patterns, and constitutional characteristics. Deep learning algorithms can analyse high-dimensional patient data, identifying subtle patterns that may elude human practitioners. Data mining techniques enhance this capacity by uncovering hidden relationships within real-world prescription data, offering valuable insights into syndrome-treatment correlations and evolving clinical practices (Li et al., 2024).

AI provides a powerful tool for tracking disease progression and predicting relapses for patients with chronic illnesses. By analysing longitudinal data from electronic health records (EHRs), AI can generate predictive models that assist practitioners in making more precise, data-informed diagnoses. Furthermore, AI can support personalised lifestyle guidance by offering tailored diet, exercise, and self-care recommendations, significantly improving patients’ quality of life while reducing the risk of relapse. These capabilities are enhanced by the rise of smart wearables, which allow for real-time health monitoring. These devices collect continuous biometric data, such as heart rate, sleep patterns, stress levels, and physical activity, which is transmitted directly to AI systems for analysis. This real-time feedback loop enables early detection of emerging health concerns. It allows patients and practitioners to take proactive, preventive action, making AI integral to ongoing care and wellness maintenance within TCM.

AI offers transformative possibilities for TCM by making data collection more dynamic, intelligent, and precise. AI tools are creating a new paradigm for personalised, preventative care, from wearable technologies to language-based diagnostic assistants. While integrating AI into the TCM diagnostic process presents challenges, particularly around the alignment of knowledge systems, it also holds the promise of a modernised yet faithful evolution of TCM. By embracing these technologies thoughtfully and collaboratively, the TCM community can harness AI to enhance diagnosis, expand access, and deepen its contributions to global health in the 21st century.

## Chapter 9: The Future Medical Diagnosis in TCM

Integrating Artificial Intelligence (AI) with Traditional Chinese Medicine (TCM) diagnostics is reshaping the future of medical diagnosis. By merging classical diagnostic principles with advanced computational methods, this fusion enhances the interpretation of chemical components and their correlation with clinical symptoms, the analysis of complex symptom patterns and the prediction of disease trajectories and the overall efficiency, accuracy, and objectivity of diagnostic outcomes.

This synergistic approach enables a deeper, data-driven understanding of the intricate relationships between chemical constituents, syndrome differentiation, and specific disease manifestations, providing a more refined and personalised diagnostic model rooted in TCM principles.

Contemporary TCM research increasingly recognises the diagnostic significance of bioactive chemical components found in herbs, bodily fluids, and pathological markers. These components are potential biomarkers for identifying diseases and therapeutic targets, offering a biochemical dimension to traditionally energetic concepts such as *Qi stagnation*, *heat toxins*, or *blood deficiency*. However, the chemical complexity of TCM formulations and the multifactorial nature of disease patterns present significant analytical challenges. Conventional tools often fail to uncover the nonlinear and multivariate interactions between chemical profiles and syndromic expressions.

AI addresses these challenges through machine learning, deep learning, and pattern recognition algorithms that can sift through large volumes of high-dimensional data to identify meaningful trends. These technologies:

* Process and categorise chemical compound data related to herbs and human physiology.
* Detect subtle, non-obvious correlations between symptoms, biochemical changes, and disease types.
* Support disease classification and syndrome differentiation with higher granularity and accuracy.
* Aid in the discovery of novel diagnostic markers and compound synergies within herbal prescriptions.

For example, deep learning models can be trained on annotated datasets to predict disease progression by analysing dynamic chemical signatures, contributing to early diagnosis and proactive risk management.

Beyond reactive diagnosis, AI’s predictive capabilities open the door to proactive, preventative care. By continuously analysing patient data—including symptoms, chemical markers, and historical trends—AI can forecast disease development, stratify patient risk, and recommend personalised interventions before the condition worsens. This represents a shift from episodic, symptom-based care to continuous health monitoring and predictive intervention, aligning closely with TCM’s focus on balance, harmony, and disease prevention.

The fusion of AI with TCM diagnostics marks a significant leap in the evolution of personalised medicine. By interpreting chemical data and integrating machine learning models, this approach enhances diagnostic accuracy and reproducibility, clinical efficiency, practitioner decision-making, patient-specific treatment strategies and long-term health outcomes. By leveraging the power of AI and the rich, structured datasets found in TCM databases, the medical community can advance toward a future where cutting-edge technologies augment TCM’s holistic wisdom. This convergence validates, modernises traditional practices, and offers a new paradigm of precise, integrative, and intelligent healthcare.

## Chapter 10: The Future of TCM Diagnosis

The future of Traditional Chinese Medicine (TCM) diagnosis lies in the seamless integration of artificial intelligence (AI) and advanced technologies to enhance diagnostic practices' accuracy, objectivity, and efficiency, while honouring and preserving TCM’s holistic principles. This evolution envisions a hybrid diagnostic system that draws on both traditional knowledge and cutting-edge tools, with key developments including:

* **AI-Powered Diagnostic Tools**: Intelligent systems for tongue, pulse, facial, and olfactory diagnostics are being developed to objectify and standardise the four traditional TCM diagnostic methods: inspection, listening/smelling, inquiry, and palpation. These tools can support clinical accuracy and reproducibility while enhancing diagnostic speed.
* **Smart Diagnostic Devices**: AI-enabled devices using sensors, computer vision, and pattern recognition can objectively interpret TCM cues, such as pulse qualities, tongue coatings, facial features, and vocal tones, mirroring the observations of experienced practitioners.
* **Advanced Data Analytics**: Machine learning and deep learning algorithms can be applied to large, diverse TCM clinical datasets to identify syndrome patterns, predict treatment efficacy, and personalise care strategies based on patient constitution and disease progression.
* **Holistic AI Models**: Future AI systems will be trained to incorporate TCM’s holistic worldview, evaluating interconnected physiological, emotional, and environmental factors to provide comprehensive health assessments and tailored treatment suggestions.
* **Chinmedomics**: This emerging discipline integrates TCM with omics technologies (e.g., genomics, metabolomics) to identify the molecular basis of TCM syndromes and herbal effects. Chinmedomics can help validate traditional diagnostic categories and refine precision treatments.
* **Molecular Profiling**: Techniques that analyse blood, urine, and stool samples at the molecular level offer objective biomarkers to complement subjective TCM diagnostics, further bridging traditional insight with modern clinical standards.

Recent advancements highlight the transformative role of AI in TCM diagnostic techniques. Recent advancements include image Recognition for standardised tongue and facial diagnosis, Sensor Technology and audio analysis algorithms for objective auscultation, Olfactory AI algorithms using odour mapping and biomarker identification for smell-based diagnostics, tactile pulse measurement devices for consistent and replicable pulse analysis, deep learning systems for nuanced symptom assessment and algorithmic support for refining and individualising treatment protocols. For these innovations to reach full potential, future efforts should focus on:

* Developing high-precision sensors to improve data reliability for sound, odour, pulse, and visual characteristics
* Training AI models on diverse, high-quality datasets to identify subtle and complex health patterns.
* Ensuring cross-device algorithm compatibility, enabling AI to analyse data from multiple hardware platforms with consistent results
* Promoting interoperability between data systems to facilitate multi-centre research and collaborative diagnostics

The future of TCM diagnosis will not be a departure from tradition but an expansion of it. By integrating AI-driven precision with the wisdom of holistic observation, we are entering a new era where diagnosis becomes more accurate, replicable, and accessible. This convergence offers a vision of intelligent, compassionate, and integrative healthcare, rooted in the past but empowered by the future.

### Objectifying TCM Diagnosis

Objectifying Traditional Chinese Medicine (TCM) diagnosis refers to using objective, technology-driven methods to assess a patient's condition, shifting away from subjective interpretations traditionally based on practitioner experience. This transformation aims to bring greater accuracy, consistency, and scientific rigour to TCM by integrating digital tools, data analytics, and algorithmic modelling. Core Components of Objectified TCM Diagnosis include:

1. **Digital Tongue Diagnosis**: Image processing and computer vision techniques are employed to analyse the tongue's colour, shape, texture, and coating. These features, which in TCM reflect organ health and internal imbalances, are now being quantitatively assessed using AI-powered tongue image analysis platforms.
2. **Pulse Waveform Analysis**: Traditional pulse diagnosis, once reliant on a practitioner’s touch and interpretation, is now being modernised through electronic sensors. These tools measure pulse depth, rhythm, intensity, and waveform to detect subtle physiological variations, transforming subjective impressions into measurable physiological data.
3. **Machine Learning and Data Analysis**: AI algorithms are being trained on vast datasets of TCM diagnostic information—including symptoms, signs, and treatment outcomes—to identify patterns, correlations, and diagnostic models. These computational tools support more precise syndrome differentiation and inform personalised treatment planning.

By relying on quantifiable data rather than practitioner intuition alone, objectification enhances the reliability and reproducibility of TCM diagnostics. Digital tools can detect subtle features and correlations often missed by the human eye or touch, supporting earlier and more accurate diagnosis. Objective data allows for standardising diagnostic protocols, enabling meaningful comparisons across clinical studies and facilitating scientific validation of TCM practices. Objectified diagnostic data can be easily shared among practitioners, researchers, and institutions, promoting greater collaboration and knowledge exchange. Despite the promise of objectification, several challenges remain:

* **Complexity of TCM Theory**: TCM relies on dynamic, holistic frameworks, such as Yin-Yang, the Five Elements, and Qi flow, which are difficult to reduce into discrete variables without oversimplifying the system.
* **Lack of Standardised Terminology and Protocols**: Variability in how symptoms and syndromes are described across TCM schools complicates the development of unified objectification models.
* **Need for Further Research and Validation**: While progress has been made, more rigorous clinical trials and algorithm training are needed to ensure that objectified tools reflect authentic TCM principles and yield accurate results.

The objectification of TCM diagnosis marks a pivotal step in the evolution of Chinese medicine in the digital age. By combining ancient wisdom with modern scientific methods, objectification enhances diagnostic accuracy, facilitates research, and strengthens communication among practitioners, without losing sight of TCM’s holistic philosophy. Ongoing investment in technology, interdisciplinary collaboration, and clinical validation will be essential to refine these tools and ensure that the spirit of TCM is preserved even as its methods are modernised. In doing so, TCM can offer a harmonised model of care that bridges tradition and innovation to benefit global health.

### Integrated TCM Diagnostic Platform

An Integrated TCM Diagnostic Platform represents a transformative step in the future of Traditional Chinese Medicine—uniting the depth of ancient diagnostic wisdom with the precision of digital technologies. These platforms enhance diagnostic accuracy, efficiency, standardisation, and collaborative knowledge-sharing among practitioners, researchers, and patients. Key Features of an Integrated TCM Diagnostic Platform include:

* **Holistic Diagnostic Framework**: True to TCM's holistic philosophy, integrated platforms synthesise information from diverse diagnostic sources—including pulse, tongue, facial features, vocal tones, symptoms, and lifestyle factors—to provide a comprehensive understanding of the patient’s physical and energetic state.
* **Advanced Digital Tools**: Leveraging artificial intelligence (AI), machine learning, and data analytics, these platforms can collect, process, and interpret a wide range of clinical data. AI-driven image recognition technologies can analyse tongue and facial images, while sensor arrays and signal processing algorithms can objectify pulse, sound, and olfactory diagnostics.
* **Personalised Treatment Recommendations**: Based on an individual’s diagnostic profile, the platform can generate tailored treatment plans, suggesting herbal formulations, acupuncture points, dietary advice, and lifestyle modifications. These personalised protocols aim to restore internal balance and address the root cause of disharmony, which is central to TCM's therapeutic model.
* **Automation for Practitioner Support**: Repetitive and time-consuming tasks, such as image analysis, symptom classification, or initial treatment recommendations, can be automated, allowing practitioners to dedicate more time to patient interaction, clinical reasoning, and therapeutic strategy.
* **Collaborative Knowledge Sharing**: By standardising and digitising diagnostic data, integrated platforms facilitate real-time collaboration and knowledge exchange between practitioners, improving continuity of care and fostering interdisciplinary learning.

To realise the full potential of an integrated TCM diagnostic platform, several developmental challenges must be addressed:

* **Standardisation and Interoperability:** Establishing unified data collection standards, terminology, and diagnostic criteria is a critical step. Harmonising these standards across devices and systems enables consistent data interpretation and supports large-scale collaborative research.
* **Multimodal Data Integration**: Future platforms must refine the ability to synchronise diverse forms of diagnostic data—pulse signals, tongue images, voice recordings, odour profiles—into coherent diagnostic outputs that align with TCM syndrome differentiation frameworks.
* **AI Model Training and Validation**: Using machine learning and classification techniques, large, annotated datasets must be collected to train AI models capable of accurately recognising and categorising TCM syndromes. This includes extensive data on pulse patterns, tongue characteristics, facial expressions, and more.
* **Quantification and Benchmarking**: The development of quantifiable metrics and performance benchmarks is essential for evaluating AI diagnostic accuracy, tracking progress, and guiding further innovation. These benchmarks also support regulatory approval and clinical acceptance of AI-assisted diagnostic tools.

The Integrated TCM Diagnostic Platform represents a bold vision for the future—objectifying ancient techniques, digitising practitioner wisdom, and unifying diagnostic practices within a seamless technological framework. By combining centuries-old knowledge with AI's analytical power, we can create a next-generation diagnostic system that is precise, scalable, and personalised, while remaining deeply rooted in the foundational principles of Traditional Chinese Medicine.

### Standardisation and Globalisation

As Traditional Chinese Medicine enters the digital age, standardisation and global integration have become essential for its continued relevance and credibility. Integrating AI into TCM diagnosis—while offering remarkable advances in objectivity and precision—demands the development of clear, uniform data collection, interpretation, and clinical application protocols.

To achieve consistency across practices, it is critical to establish standardised diagnostic frameworks, terminologies, and performance metrics that define how pulse, tongue, facial, auditory, and olfactory data are measured, analysed, and interpreted. These frameworks must honour the integrity of TCM’s holistic principles and align with the rigorous expectations of scientific and technological systems.

Establishing international standards, such as those supported by the International Organisation for Standardisation (ISO) and the World Health Organisation (WHO), will play a central role in this transformation. These global benchmarks will help ensure:

* Quality and safety in AI-driven diagnostics
* Reproducibility and reliability across clinical settings
* Interoperability between digital diagnostic platforms and medical devices
* Global collaboration in research, training, and clinical implementation

Standardisation will also lay the foundation for regulatory approval and institutional adoption of TCM diagnostic technologies in healthcare systems worldwide. As a result, AI-enhanced TCM will gain greater recognition within evidence-based medicine and contribute meaningfully to the broader movement toward integrative and personalised healthcare.

Ultimately, the globalisation of TCM—powered by standardised, AI-supported diagnostic systems—offers a future where ancient wisdom and cutting-edge innovation coexist. Building a common language between tradition and technology and across nations and cultures can unlock TCM's full potential to promote health, healing, and harmony worldwide.

# PART 2: AI In TCM Research

Integrating Artificial Intelligence (AI) into Traditional Chinese Medicine (TCM) research marks a transformative shift in how ancient wisdom is studied, applied, and advanced. No longer confined to oral transmission or classical texts, TCM knowledge is being digitised, analysed, and reinterpreted through the lens of modern computational science. AI enables researchers to uncover patterns, validate clinical efficacy, and generate new insights by processing complex and voluminous TCM data that spans centuries of empirical practice. This convergence of traditional healing and intelligent technology heralds a new era, where TCM can evolve into a more standardised, data-driven, and globally recognised medical system without losing its holistic essence.

Central to this evolution are robust TCM databases, AI-driven data mining, knowledge acquisition methods, and the construction of knowledge graphs—tools that enable the systematic organisation and exploration of traditional knowledge. The possibility of creating an integrated TCM repository—one central, intelligent platform for accessing and expanding the entire body of TCM knowledge—holds immense potential. Collectively, these innovations are reshaping the landscape of TCM research, bridging tradition and technology to ensure that the wisdom of the past continues to inform and empower future medicine.

## Chapter 11: TCM Databases

TCM databases are vibrant repositories of ancient herbal wisdom, diagnostic techniques, and clinical case records. Today, they form the backbone of AI systems capable of learning, predicting, and evolving with remarkable precision. These databases serve as comprehensive resources, seamlessly enabling data exchange for drug discovery, clinical trials, and a deeper understanding of the fundamental mechanisms underpinning TCM. Core Information Contained in TCM Databases:

* TCM prescriptions
* Herbs and medicinal materials
* Chemical ingredients and compounds
* Biological targets
* Associated diseases and symptoms.
* Component identification
* Biological pathways
* Symptom mapping
* Historical and linguistic data

TCM databases enhance research efficiency, accuracy, and scope by providing accurate, standardised information. They streamline manual data collection, significantly reduce the time and resources required for analysis, and offer a centralised knowledge base for students, researchers, and clinicians. Importantly, these databases also foster interdisciplinary collaboration—encouraging the convergence of pharmacology, bioinformatics, data science, and traditional medicine. This fusion enhances the understanding of TCM’s therapeutic potential and supports its integration into mainstream global healthcare systems. The emergence of TCM databases has revolutionised the research landscape. They facilitate access to critical information, accelerate innovation, foster cross-domain partnerships, and pave the way for a digitally empowered future of Traditional Chinese Medicine.

TCM databases offer many features that significantly advance Traditional Chinese Medicine research. By providing reliable, diverse, and standardised information, alongside specialised tools, they enable in-depth exploration of complex therapeutic relationships and patterns. Large-scale databases supply abundant, high-quality training samples essential for developing and refining AI models.

The ongoing expansion of these databases is critical. As the volume and granularity of data grow, so does the precision, relevance, and contextual adaptability of AI applications in TCM. Enhanced datasets allow AI systems to better navigate the subtleties of TCM diagnosis and treatment, enabling them to adapt across diverse clinical scenarios and patient populations. This improves the robustness of digital health tools and accelerates the integration of TCM into evidence-based, personalised healthcare solutions.

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| Database | Overview | Website |
| **TCMBank** | TCMBank is the largest non-commercial TCM database, encompassing over 9,000 herbs, 61,000 ingredients, 15,000 targets, and 32,000 diseases. It provides 3D structures of ingredients and integrates AI-assisted drug discovery tools, making it a valuable resource for modern drug development. | <https://tcmbank.cn/> |
| **ETCM (Encyclopedia of Traditional Chinese Medicine)** | ETCM offers comprehensive information on TCM herbs, formulas, ingredients, and their relationships with gene targets and diseases. It includes over 48,000 formulas and nearly 10,000 Chinese patent drugs, facilitating systematic analysis and network construction for research purposes. | https://www.tcmip.cn/ETCM/ |
| **TCMSP (Traditional Chinese Medicine Systems Pharmacology Database and Analysis Platform)** | TCMSP integrates pharmacokinetic properties, drug-likeness, and target information for 499 Chinese herbs. It provides tools for analysing herb-compound-target-disease networks, aiding in understanding TCM mechanisms and drug discovery processes. | <https://www.tcmsp-e.com/> |
| **TCMM (Traditional Chinese Medicine Modernisation Database)** | TCMM focuses on modernising TCM by aligning traditional knowledge with modern medical insights. It includes over 3 million records covering prescriptions, ingredients, targets, and diseases, and offers tools like Rx Gen for customisable prescription generation. | https://www.tcmm.net.cn/en/ |
| **TCMID (Traditional Chinese Medicine Integrated Database)** | TCMID integrates data on over 8,000 herbs, 25,000 herbal compounds, and 17,500 targets. It bridges TCM with modern life sciences, providing a platform for exploring herb-compound-target-disease relationships. | https://www.bidd.group/TCMID/ |
| **Chem-TCM (Chemical Database of Traditional Chinese Medicine)** | Chem-TCM contains chemical information on approximately 350 herbs, listing over 12,000 chemical records. It links botanical information with Western therapeutic targets, aiding in assessing molecular activity within TCM categories. | <https://ebrary.net/88641/> computer\_science/databases |
| **Integrated Traditional Chinese Medicine (ITCM)** | ITCM integrates ten TCM-related databases, including information from various pharmacopoeias and official recommendations for COVID-19 formulas. It serves as a comprehensive resource for TCM research and application. | https://itcm.biotcm.net/ |
| **The Chinese Medicine Database** | A comprehensive clinical tool featuring over 680 single herbs, 1,485 formulas, 361 acupuncture points, and 15,000 Western diagnoses (including ICD-9 codes). It also includes a Medical Chinese dictionary with over 100,000 words and unique translations of classical Chinese texts. | [chinesemedicinedatabase.com](https://chinesemedicinedatabase.com/) |
| **Yin Yang House TCM Herb Database** | Offers detailed information on the majority of herbs used in clinical settings worldwide. Herbs are categorised by function, channel, and property, providing insights into their traditional uses and applications. | yinyanghouse.com |
| **Me & Qi Herb Database** | Focuses on commonly used TCM herbs, providing pictures and overviews of their sources, basic nature, actions, usage, and safety profiles. | meandqi.com |
| **Wiseman’s Chinese Medical Database (ChiMedBase)** | Developed by Nigel Wiseman, this database includes over 30,000 Chinese terms with Pinyin transcription and English translation, 6,000 medicinal, 2,000 formulas, and detailed information on approximately 400 acupuncture points. | [chinese-medical-database.com](https://chinese-medical-database.com/) |
| **Traditional Chinese Medicine Database System** | Developed by the China Academy of Chinese Medical Sciences, this system encompasses 48 databases with over 2.2 million records, including TCM journal literature, disease diagnosis and treatment, various herbal databases, formulas, and national standards. | cintmed. cintcm.cn |
| **TCMD-2013-Eng (Traditional Chinese Medical Database)** | An English-language database containing detailed data and standard specifications of many traditional Chinese medicines, facilitating convenient searching and supporting research and development of new drugs. | repharma.pku.edu.cn |
| **TCMID (Traditional Chinese Medicine Integrated Database)** | TCMID integrates data on over 8,000 herbs, 25,000 herbal compounds, and 17,500 targets. It bridges TCM with modern life sciences, providing a platform for exploring herb-compound-target-disease relationships. | https://www.bidd.group/TCMID/ |
| **Chem-TCM (Chemical Database of Traditional Chinese Medicine)** | Chem-TCM contains chemical information on approximately 350 herbs, listing over 12,000 chemical records. It links botanical information with Western therapeutic targets, aiding in assessing molecular activity within TCM categories. | <https://ebrary.net/88641/> computer\_science/databases |
| **TCM Gene-Disease Association Database (TCMGeneDIT)** | TCMGeneDIT is a database that uses text mining techniques to associate TCM herbs with genes and diseases. It facilitates the exploration of molecular mechanisms underlying TCM therapies. | <https://ebrary.net/88641/> computer\_science/databases |
| **HIT (Herbal Ingredients' Targets) Database** | HIT links herbal active ingredients to their molecular targets, providing insights into the pharmacological actions of TCM herbs | <https://ebrary.net/88641/> computer\_science/databases |
| **TCM-SD (Traditional Chinese Medicine Syndrome Differentiation)** | TCM-SD is a benchmark dataset for probing syndrome differentiation via natural language processing. It contains over 54,000 real-world clinical records covering 148 syndromes, supporting AI-driven TCM research. | <https://arxiv.org/abs/2203.10839> |
| **BianCang: A Traditional Chinese Medicine Large Language Model** | BianCang is a TCM-specific large language model trained on extensive TCM corpora. It enhances diagnostic and differentiation capabilities, offering valuable insights for future research. | <https://arxiv.org/abs/2411.11027> |
| **Hengqin-RA-v1: Advanced LLM for TCM Rheumatoid Arthritis Diagnosis** | Hengqin-RA-v1 is a large language model tailored for TCM diagnosis and treatment of rheumatoid arthritis. It utilises a comprehensive RA-specific dataset curated from ancient Chinese medical literature and modern clinical studies. | <https://arxiv.org/abs/2501.02471> |

### The Role of Herbal Medicine Databases in TCM Research

Herbal medicine databases are foundational in advancing Traditional Chinese Medicine (TCM) research and applications. These repositories not only preserve TCM's rich historical and cultural legacy but also enable deep investigations into its global impact and therapeutic efficacy. By systematically cataloguing medicinal materials, chemical constituents, pharmacological actions, and clinical applications, these databases provide essential infrastructure for herbal research, drug discovery, and the scientific validation of traditional remedies.

Integrating Artificial Intelligence (AI) into these databases has further elevated their value. Machine learning algorithms and neural networks are increasingly employed to preprocess and extract meaningful features from complex herbal chemical datasets. Key preprocessing steps—such as data cleansing, normalisation, and transformation—ensure the data is consistent, accurate, and ready for analysis. AI models are then used to identify latent patterns, reduce complexity, and cluster similar compounds based on their chemical structure or pharmacological activity.

Beyond classification, AI enables the construction of powerful predictive models that forecast the biological activities of herbal compounds. Leveraging the vast and intricate datasets housed in TCM databases, these models can identify potential bioactive ingredients and novel drug candidates with specific therapeutic targets. This predictive capability accelerates the drug discovery process, offering a modern scientific approach to validating and expanding upon traditional herbal wisdom. As a result, AI-powered herbal medicine databases are becoming indispensable tools in the modernisation of TCM and its integration into global healthcare innovation.

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| Database | Database | Focus Area | Key Features / Examples | Website |
| Traditional Chinese Medicine Integrated Database | TCMID | Integrated TCM database of herbs, compounds, targets, diseases, and formulas | Includes 47,000 prescriptions, 8,000 herbs, and 25,000 ingredients | http://www.megabionet.org/tcmid/ |
| Traditional Chinese Medicine Systems Pharmacology Database and Analysis Platform | TCMSP | Pharmacokinetics, targets, and systems pharmacology | Allows network pharmacology analysis with oral bioavailability data | <https://old.tcmsp-e.com/> |
| Symptom Mapping for TCM | SymMap | Mapping TCM symptoms to biomedical terminology | Links TCM symptoms like 'heat syndrome' to biomedical disorders | <https://www.symmap.org/> |
| Encyclopedia of Traditional Chinese Medicine | ETCM | Encyclopaedic entries on TCM herbs, formulas, diseases, and targets | bioactivity, clinical use, and molecular targets for 400+ herbs | <http://www.tcmip.cn/ETCM/index.php/>  Home/Index/index.html |
|  | TCM-Mesh | Mechanistic analysis of herbs in treating diseases | Constructs herb-target-disease networks for complex disease research | <http://mesh.tcm.microbioinformatics.org/> |
| Herbal Ingredients’ Targets Database | HIT | Herbal ingredients and their protein targets | Connects 1,200 herbal ingredients to over 3,000 known protein targets | <http://lifecenter.sgst.cn/hit/> |
| Bioinformatics Analysis Tool for Molecular Mechanism of TCM | BATMAN-TCM | Target prediction for TCM ingredients via similarity-based algorithms | Predicts interactions and supports multi-component therapeutic analysis | <http://bionet.ncpsb.org/batman-tcm/> |
|  | KNApSAcK | Phytochemical information for a wide variety of plant species | Identifies plant-derived compounds and maps them to disease targets | <http://www.knapsackfamily.com/KNApSAcK/> |
|  | NAPRALERT | Ethnopharmacological data on natural products | Covers over 200,000 articles on natural compound bioactivity | <https://www.napralert.org/> |
| Indian Medicinal Plants, Phytochemistry and Therapeutics | IMPPAT | Phytochemistry and therapeutic data on Indian medicinal plants | Contains 1,700+ Indian plants, 9,500 phytochemicals, and 1,100 therapeutic uses | <https://cb.imsc.res.in/imppat/> |

## Chapter 12: AI-Based Data Mining

Data mining in Traditional Chinese Medicine (TCM) involves using computational techniques to analyse large datasets of TCM information (such as medical records, herbal prescriptions, and ancient texts) to extract meaningful patterns and knowledge. This helps in understanding the effectiveness of TCM treatments, identifying potential drug candidates, and optimising TCM practices. Applications of Data Mining in TCM:

* **Analysing TCM Prescriptions:** Data mining can help identify patterns in TCM prescriptions, such as which herbs are commonly used together and how they relate to specific symptoms or diseases.
* **Understanding TCM Theory:** By analysing ancient TCM texts, data mining can help uncover the underlying principles and theories of TCM, such as the five elements, yin and yang, and the flow of qi.
* **Developing New TCM Treatments:** Data mining can help identify potential new TCM treatments by analysing large datasets of herbal ingredients and their effects.
* **Improving TCM Diagnostics:** Data mining can be used to develop more accurate and efficient diagnostic tools for TCM by analysing patient data and patterns.
* **Optimising TCM Manufacturing Processes: Data mining can help optimise** the manufacturing processes of TCM products, such as herbal medicines, by identifying critical process parameters and improving quality control.
* **Researching TCM-Related Diseases:** Data mining can be used to analyse large datasets of patient records and research articles to identify the relationships between TCM and various diseases, such as COVID-19, depression, and insomnia.

Data Mining Techniques Used in TCM include association rules mining, clustering analysis, factor analysis, topic modelling and deep learning. Examples of Data Mining Applications in TCM:

* **Identifying Core Herb Pairs:** Data mining can identify the most frequently used pairs of herbs in TCM prescriptions.
* **Summarising the Utility and Attributes of TCM Prescriptions:** Data mining can analyse the characteristics and effects of different TCM prescriptions.
* **Finding the Optimal Dose of Chinese Herbs:** Data mining can help determine the optimal dosage for different conditions.
* **Developing New TCM Prescriptions:** Data mining can help generate new TCM prescriptions based on existing knowledge and data.
* **Identifying Drug Candidates:** Data mining can help identify potential drug candidates based on TCM for treating depression.

Large-scale data mining can uncover new knowledge from clinical experience, literature, and databases. Machine learning has discovered novel combinations and network pharmacology relationships when applied to databases.

Using AI to integrate data from various TCM databases, including chemical, clinical and pharmacological data, significantly enhances the comprehensiveness and accuracy of diagnostics. This holistic data analysis approach ensures that all relevant aspects of patient health are considered, resulting in more informed and effective diagnostic outcomes. The integration process involves advanced data mining techniques and AI algorithms capable of handling the complexity and diversity of TCM data.

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| **Data Mining Techniques**  **Association Rules Mining i**dentifies relationships between different items or concepts in the data.  **Clustering Analysis g**roups similar data points together based on their characteristics.  **Factor Analysis r**educes the number of variables in a dataset by identifying underlying factors.  **Topic Modelling i**dentifies the underlying themes or topics in a dataset of text.  **Deep Learning u**tilises neural networks to analyse complex data patterns. |

## Chapter 13: TCM Knowledge Acquisition and Novel Knowledge Validation

Knowledge acquisition in Traditional Chinese Medicine (TCM) is the systematic process of collecting, interpreting, and structuring knowledge from classical texts, clinical experience, and empirical data to improve the field's understanding, diagnosis, treatment, and innovation.

Historically, TCM knowledge was transmitted through classical literature such as the *Huangdi Neijing*, case studies, and master-apprentice relationships. In the modern context, this process has expanded to include digital databases, clinical records, and biomedical research. With the rise of artificial intelligence and data science, the field of TCM knowledge acquisition is undergoing a radical transformation. Key Aspects of the TCM Knowledge Acquisition process include:

1. **Classical Knowledge Extraction**: This involves extracting valuable diagnostic and therapeutic information from ancient texts written in Classical Chinese. Natural language processing (NLP) and machine learning techniques are now used to digitise and analyse these texts, facilitating greater accessibility and interpretation.
2. **Clinical Data Mining**: Systematically analysing electronic medical records, treatment protocols, and patient outcomes. AI tools help identify patterns and correlations that may not be immediately evident, allowing clinicians and researchers to refine syndrome differentiation and treatment strategies.
3. **Standardisation and Ontology Development**: Creating structured vocabularies, taxonomies, and knowledge graphs for TCM concepts such as syndromes, herbs, acupoints, and formulas. This enables interoperability across systems, facilitates education, and supports AI training models.
4. **Multi-source Integration**: Combining data from herbal medicine, acupuncture, imaging, pulse diagnosis, genomics, and patient-reported outcomes. AI integrates and cross-validates this information, providing a more holistic understanding of health and disease.

The evolving field of TCM knowledge acquisition, powered by AI and big data, marks a shift from static knowledge preservation to dynamic knowledge generation. Novel knowledge bridges traditional wisdom with modern science, ensuring that TCM remains a living, adaptive system capable of meeting the demands of 21st-century healthcare. This integration enhances clinical efficacy and innovation and upholds the integrity of TCM’s holistic worldview in a rapidly changing medical landscape.

### Chinese Medicine Network Research

Chinese Medicine Network research represents a groundbreaking initiative to express and validate Traditional Chinese Medicine (TCM) theories through quantitative models. By integrating systems biology, pharmacology, and network science, this research transforms TCM's traditionally qualitative framework into structured, computational forms that can be analysed, validated, and applied in a modern context. This approach leverages two complementary strategies—top-down and bottom-up—to design and refine herbal prescriptions and understand the complex mechanisms underlying disease and therapy.

* **Top-Down Approach: From Classical Formulas to New Applications:** The top-down strategy begins with established classical prescriptions and knowledge-rich starting points. Researchers use network analysis to dissect these prescriptions, mapping the relationships between herbs and their active compounds, biological targets and pathways, disease networks, and symptom clusters. This analysis enables the rational modification or reassembly of existing formulas to enhance efficacy, reduce toxicity, or tailor them to specific modern clinical needs. For instance, by understanding how a classical formula like *Liu Wei Di Huang Wan* interacts with kidney-related disease pathways, researchers can design new variants optimised for diabetic nephropathy or hypertension.
* **Bottom-Up Approach: Data-Driven Prescription Design from Disease Networks:** The bottom-up approach does not rely on existing prescriptions. Instead, it starts by constructing disease-related networks based on genomic, proteomic, and clinical data. These networks identify critical disease-related targets and pathways, which are then matched to herbal components using computational tools such as network pharmacology, target prediction algorithms, machine learning models. Through this process, entirely new TCM formulas can be designed based on objective disease mechanisms. This approach is particularly promising for emerging diseases, complex syndromes, or conditions where classical prescriptions offer limited guidance.

Chinese Medicine Network research bridges the traditional wisdom of TCM with modern biomedical science, offering several key benefits quantitative validation of ancient theories and empirical knowledge, personalised prescription design, tailored to patient-specific biomolecular profiles, scientific standardisation, improving reproducibility and regulatory acceptance and accelerated drug discovery by identifying multi-target, multi-pathway herbal combinations. By combining the top-down reverence for classical knowledge with the bottom-up power of modern data science, Chinese Medicine Network research marks a transformative step in the modernisation and globalisation of TCM.

## Chapter 14: Knowledge Graph Construction

Knowledge graph construction is a transformative method for digitising and organising the vast and complex body of Traditional Chinese Medicine (TCM) knowledge. It provides a structured, interconnected framework that maps relationships among herbs, symptoms, syndromes, diagnostic methods, and treatment strategies. This approach enables more intelligent, efficient, and scalable applications of TCM in both clinical and research settings.

* 1. **Representation Learning and Chemical Data Organisation**: Representation learning is central to constructing knowledge graphs in TCM. By encoding entities (e.g., herbs, formulas, symptoms, compounds) and their relationships as vector representations, AI models can better understand the semantics and associations within the TCM corpus. This enables efficient information retrieval across large TCM databases, semantic search and recommendation (e.g., finding similar herbs or prescriptions), and improved chemical and pharmacological data organisation within the TCM knowledge base. This supports advanced applications in drug discovery, clinical decision support, and educational tools.
  2. **Mixed-Scale Graph Learning for Formula Optimisation**: Mixed-scale graph learning allows researchers to analyse and predict effective herbal combinations by examining multi-layered interactions between herbs and their active chemical compounds, compound–compound synergies or antagonisms and herbs and therapeutic targets across multiple diseases. This method provides insights into formula optimisation, uncovering patterns that guide the discovery or refinement of prescriptions for improved efficacy and safety.

The foundation of TCM’s practical wisdom lies in centuries of clinical experience. Digitising this body of knowledge involves meticulously collecting and curating real-world data from clinical records, including patient complaints and symptom patterns, pulse and tongue diagnostics, syndromic classifications, treatment strategies, and outcomes. This raw data is then structured and formalised using knowledge engineering techniques. The structured data populates the TCM knowledge graph, linking clinical features with diagnostic patterns, herbs, acupoints, and treatment outcomes. Once structured, the data is deployed into a web-based knowledge graph platform. This enables advanced visualisation of TCM relationships and clinical reasoning pathways, development of intelligent recommendation systems that suggest treatments based on patient input and historical cases and support for automated or semi-automated diagnosis and treatment planning. Educational tools for students and practitioners to explore diagnostic logic and formula composition.

These graphs promote a nuanced, interconnected understanding of TCM principles and therapeutic strategies. Knowledge graphs are powerful tools to modernise TCM while preserving its holistic essence by supporting real-time decision-making, intelligent querying, and automated reasoning.

**TCM Knowledge Graphs**

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| --- | --- | --- | --- | --- |
| Knowledge Graph | Developed By | Features | Functions | Applications |
| **TCMKG (Traditional Chinese Medicine Knowledge Graph)** | Institute of Computing Technology, Chinese Academy of Sciences | Integrates herbs, symptoms, diseases, syndromes, prescriptions, and compounds. | Supports semantic search, diagnosis assistance, and prescription generation. | Used in TCM recommendation systems and intelligent consultation bots. |
| **TCMGeneDIT** | Database initiative by TCM researchers | Links TCM herbs with diseases, genes, proteins, and chemical constituents. | Supports drug discovery, systems biology, and mechanistic research. | Network pharmacology, gene-target exploration. |
| **HerbKG** | Zhejiang University | Focuses on herbal medicine, integrating herb–compound–disease–gene interactions. | Enables pathway analysis and drug repurposing. | Herbal formulation analysis and compound screening. |
| **SymMap** | Shanghai University of Traditional Chinese Medicine | Maps TCM symptoms with modern biomedical diseases, herbs, and targets. | Enables comparison between TCM and Western medicine symptoms. | Translational medicine, symptom ontology alignment. |
| **ETCM (Encyclopedia of Traditional Chinese Medicine)** | School of Life Science, China Pharmaceutical University | Contains over 1,400 herbs, 44,000 formulas, and related molecular info. | Supports prescription decoding, target prediction, and disease matching. | Clinical reference and drug design. |
| **YaTCM** | Systems pharmacology group, Dalian University of Technology | Incorporates TCM formulas, pharmacokinetic data, and bioactivity evidence. | Facilitates herb-syndrome-disease analysis. | AI training sets for herbal efficacy and interaction modelling. |
| **BencaoZhiku Knowledge Graph** | Chengdu University of TCM | Holds over 40 million herbal compounds and 15 million species records. | Links plant species, compound structures, and clinical applications | Herb authentication, quality control, and pharmaceutical R&D. |
| **TCM-Mesh** | Multiple Chinese research institutes | Knowledge network integrating herbs, diseases, gene ontology, and phenotypes. | Performs mesh-style inference for drug development and mechanistic research. | Network pharmacology and personalised treatment matching. |
| **Huatuo Knowledge Graph** | Research teams working on HuatuoGPT | Supports interactive Q&A, linking herbs, formulas, symptoms, and modern terminology. | Backend for HuatuoGPT consultation AI. | Real-time TCM decision-making and education. |
| **TCMM (Traditional Chinese Medicine Modernisation) Knowledge Graph** | AI-HPC Research Team | Integrates six high-quality TCM and Western medicine databases, encompassing 20 entities and 46 kinds of relations, totalling over 3.4 million records. | Facilitates advanced data integration, enabling comprehensive analysis of biological processes, pathways, anatomical sites, and side effects. | Supports modernised TCM research and development by providing a unified intelligence platform. |
| **OpenTCM Knowledge Graph** | The research team was led by Jinglin He et al. | Constructed from over 68 classical Chinese medical texts, resulting in a multi-relational knowledge graph with more than 48,000 entities and 152,000 interrelationships. | Serves as the backbone for the OpenTCM system, enabling GraphRAG-powered large language models (LLMs) for TCM knowledge retrieval and diagnosis. | Enhances TCM ingredient search and diagnostic question-answering without requiring pre-training or fine-tuning of LLMs. |
| **GraphAI-for-TCM** | Zeng Jingqi | This project complements the Traditional Chinese Medicine Multi-dimensional Knowledge Graph (TCM-MKG) project, which focuses on quantifying compatibility mechanisms within TCM. | Employs graph neural networks (GNNs) to analyse and interpret the intricate compatibility relationships within TCM formulations. | Facilitates advanced TCM compatibility studies, aiding in the quantitative evaluation of herbal combinations |
| **TCM-Ladder Benchmark** | Jiacheng Xie et al. | A multimodal question-answering dataset designed for evaluating large TCM language models, encompassing over 52,000 questions across various TCM disciplines. | Provides a standardised benchmark for assessing the performance of TCM-specific LLMs on real-world tasks. | Supports the development and evaluation of AI models in TCM education and clinical decision-making |
| **MTCMB (Multi-Task Benchmark for TCM)** | Shufeng Kong et al. | Comprises 12 sub-datasets spanning five major categories: knowledge QA, language understanding, diagnostic reasoning, prescription generation, and safety evaluation. | Serves as a comprehensive testbed for evaluating LLMs on TCM knowledge, reasoning, and safety. | Guides the development of more competent and trustworthy medical AI systems in the TCM domain. |
| **TCM-MKG (Traditional Chinese Medicine Multi-dimensional Knowledge Graph)** | Jingqi Zeng (2024) | Integrates data from over 30 authoritative resources, encompassing TCM terminology, Chinese patent medicines, herbal pieces, natural products, chemical components, disease targets, and more. |  | Bridges traditional TCM knowledge with modern biomedical sciences, facilitating research and application in both domains. |
| **TCMKD (Traditional Chinese Medicine Knowledge Database)** |  | Comprises 143,331 entities and 3,609,559 relationships, constructed using seven types of previously organised data. |  | Provides a comprehensive platform for TCM research, enabling advanced queries and analysis of TCM knowledge. |
| **TCM-ERE (Traditional Chinese Medicine Entity and Relation Extraction)** | Research team led by Fan et al. | Defines an ontology with 29 types of entities and 32 kinds of relations, annotated in a high-quality entity and relation extraction dataset. |  | Facilitates the construction of domain-specific knowledge graphs in TCM, enhancing information retrieval and knowledge discovery. |
| **GraphAI-for-TCM** | Jingqi Zeng and Xiaobin Jia (2024) | Applies graph neural networks to model and analyse 6,080 Chinese herbal formulas, introducing medicinal properties as virtual nodes. |  | Quantitatively assesses the roles of Chinese herbal pieces within formulas, aiding in the understanding of compatibility mechanisms in TCM. |
| **SCEIKG (Sequential Condition Evolved Interaction Knowledge Graph)** | Jingjin Liu et al. | Models the dynamics of patient conditions over multiple visits, incorporating interactions between herbs and patient conditions. |  | Enhances the accuracy of TCM prescription recommendations by considering the temporal evolution of patient states. |
| **ChatGLM3-6B TCM Knowledge Graph** | Bo Zhang and Ruifang Li | Utilises a fine-tuned ChatGLM3-6B model for TCM-related question-and-answer tasks, extracting key entities via a specialised TCM entity recognition model (TCMER). |  | Supports the construction and application of TCM knowledge graphs, enhancing information retrieval and decision-making in TCM. |
| **TCM Knowledge Graph Based on Large Language Models** | Yichong Zhang and Yongtao Hao | Leverages large language models to collect and embed substantial TCM-related data, generating precise representations transformed into a knowledge graph format. |  | Aids in teaching, disease diagnosis, and treatment decisions contribute to TCM modernisation. |

## Chapter 15: TCM Repository

The author of *Integrating AI and TCM* envisions a future where the full breadth of Traditional Chinese Medicine (TCM) knowledge is unified into a single, comprehensive digital repository. Imagine a digitalised and interconnected web-based platform that houses the entirety of TCM resources—classical texts, herbal compendia, clinical case records, diagnostic patterns, acupoint atlases, pharmacopoeias, and modern research.

This centralised TCM knowledge base would be designed for high accessibility and interoperability. Practitioners, researchers, educators, and patients could easily retrieve information with intuitive search tools and structured metadata. More importantly, this repository would not be static—it would serve as a dynamic, evolving foundation for training artificial intelligence systems, including large language models (LLMs) and domain-specific AIs tailored to the nuances of TCM.

By integrating disparate TCM databases—currently housed in isolated institutions or scattered across various platforms—this unified system would provide:

* **Standardised, machine-readable formats** for herbs, formulas, diagnostic patterns, and treatment protocols
* **Linked knowledge graphs** showing relationships between symptoms, herbs, syndromes, and pathways.
* **Historical and contemporary insights** woven together to preserve lineage while encouraging innovation.
* **A multilingual interface** to make TCM knowledge accessible across cultures and regions.
* **An open platform for AI training**, enabling the development of more accurate, culturally competent, and clinically relevant TCM-AI systems.

Such a platform would revolutionise how TCM is taught, practised, and evolved in the digital age. It would empower not only AI models but also human practitioners, fostering collaboration between ancient healing wisdom and modern technological advancement. Ultimately, this digital integration would mark a critical step toward globalising TCM and securing its relevance in the 21st century and beyond.

# PART 3: AI in Herbal Medicine

As artificial intelligence (AI) technology continues to evolve, its integration with herbal medicine marks the beginning of a transformative era that bridges the profound wisdom of Traditional Chinese Medicine (TCM) with the precision and capabilities of modern science. AI is emerging as a powerful catalyst in the research, development, and clinical application of herbal therapies, particularly in the following domains:

* Chemical component analysis
* Pharmacological mechanism exploration
* New drug discovery
* Quantitative and qualitative herb analysis
* Herb classification and identification
* Chemical profiling and standardisation

AI's unparalleled ability to process vast and complex datasets, uncover hidden patterns, and generate predictive models greatly surpasses the limitations of traditional research methods. This synergy between AI and herbal medicine unlocks deeper therapeutic insights and redefines how herbal knowledge can be applied in modern healthcare.

The complexity of herbal medicine—characterised by multifaceted interactions among numerous bioactive compounds—makes it a natural candidate for AI-enhanced analysis. Each herbal formula involves a dynamic interplay of ingredients that affect the body in intricate and often nonlinear ways. Understanding and optimising these interactions requires tools capable of high-level data integration and pattern recognition—capabilities at the core of AI systems.

AI enhances the accuracy, consistency, and efficacy of herbal diagnostics and treatments by adopting systematic, data-driven, and highly precise methodologies. More than just a technological advancement, this integration represents a paradigm shift: a movement toward intelligent herbal medicine that respects traditional foundations while embracing the innovations of the digital age.

## Chapter 16: The Identification, Classification and Recognition of Herbs

Artificial Intelligence (AI) is playing a transformative role in the identification and classification of herbal medicines by enabling the precise analysis of their chemical, physical, and pharmacological properties. Machine learning and deep learning technologies, in particular, are highly effective in analysing complex, high-dimensional data, making them ideal for interpreting the intricate chemical profiles of herbs.

These technologies facilitate the detailed characterisation of herbal components, helping researchers better understand their therapeutic effects, mechanisms of action, and potential interactions. This supports the discovery of novel applications for traditional herbs and enhances the standardisation, authentication, and quality control of herbal products—a crucial step toward ensuring consistency, safety, and regulatory compliance in clinical practice.

AI systems also address one of the greatest challenges in herbal medicine research: managing the vast and heterogeneous data generated from centuries of empirical knowledge, modern pharmacological studies, and chemical profiling. By applying data mining and network pharmacology approaches, AI helps reveal patterns and relationships within complex herbal formulations, offering insights into herb–herb interactions and the synergistic effects that underpin many traditional prescriptions.

Furthermore, AI excels in automated herb classification by analysing morphological features (e.g., leaf shape, colour, texture) and molecular fingerprints. Image recognition systems can identify herbal species with remarkable accuracy, while chemical analysis supported by AI can classify herbs based on active constituents, toxicity, and pharmacodynamic properties. Ultimately, AI is accelerating the scientific validation of herbal medicine and paving the way for a more standardised and mechanistic understanding of how traditional remedies work, making them more accessible, evidence-based, and globally integrated in modern healthcare systems.

## Chapter 17: Herbal Screening

AI plays a pivotal role in herbal screening by dramatically enhancing the speed, precision, and scope of identifying bioactive compounds in herbs and predicting their therapeutic effects. Here’s how AI works across the herbal screening process:

* **Data Collection and Integration:** AI begins by processing large datasets that include traditional knowledge, pharmacological studies, chemical profiles, and genomic data of medicinal plants. Sources include classical TCM literature, pharmacopoeias, clinical trial data, high-throughput screening outputs and molecular databases (e.g., PubChem, TCMID, BATMAN-TCM). AI systems integrate these heterogeneous datasets to create a comprehensive knowledge base for herbal screening.
* **Feature Extraction and Compound Analysis:** Machine learning (ML) algorithms are used to extract key features from herbal data including chemical structure (molecular fingerprints, SMILES notation), pharmacokinetics (ADME properties: absorption, distribution, metabolism, excretion), toxicity profiles and target prediction (which proteins or receptors a compound may bind to). Techniques like quantitative structure–activity relationship (QSAR) modelling and deep learning can predict biological activity based on chemical properties.
* **Bioactivity Prediction:** AI models screen thousands of herbal compounds against known disease targets using supervised learning (e.g., SVM, random forests) to classify compounds as active/inactive, neural networks to find non-obvious patterns between structure and efficacy and docking simulations with AI-enhanced scoring systems to predict how strongly compounds bind to molecular targets. This reduces the time and cost traditionally associated with wet-lab bioassays.
* **Network Pharmacology and Systems Mapping:** AI maps out the multi-target nature of herbal compounds by constructing herb–compound–target–disease (H-C-T-D) networks, pathway enrichment analyses showing how compounds influence biological systems and mechanism-of-action models, revealing how complex herbal formulations exert therapeutic effects. This aligns with the holistic philosophy of TCM, where herbs affect multiple pathways rather than a single target.
* **Compound Prioritisation:** AI ranks compounds based on predicted efficacy, safety, drug-likeness and synergistic potential with other herbs. This helps researchers focus on the most promising bioactive candidates for further testing or drug development.
* **Continuous Learning:** As new experimental data becomes available, AI models are retrained and refined, improving prediction accuracy over time. This iterative loop ensures the herbal screening process becomes more intelligent and effective with use.

AI revolutionises herbal screening by combining traditional knowledge with modern data science. This allows faster identification of promising herbal compounds, deeper understanding of pharmacological effects, and safer and more effective integration of herbal treatments into contemporary medicine. This accelerates herbal drug discovery and modernises and validates centuries of TCM wisdom through scientifically rigorous methods.

## Chapter 18: TCM Formula Discovery

AI is transformative in discovering traditional Chinese medicine (TCM) formulas, helping modernise and accelerate what was once largely an experience-based and intuitive process. By analysing vast datasets, uncovering hidden patterns, and modelling complex herb interactions, AI allows researchers and practitioners to identify, optimise, and even design new herbal formulas with greater precision, safety, and scientific validity. Here’s how AI contributes to TCM formula discovery:

* **Mining Classical Texts and Clinical Records:** AI leverages natural language processing (NLP) to extract structured knowledge from classical TCM literature, ancient prescriptions, and modern clinical case records. This includes identifying commonly used herbal combinations for specific patterns or conditions, extracting dosage patterns, contraindications, and treatment outcomes and structuring unstandardised textual information into searchable, analysable databases. By doing so, AI helps preserve and revitalise traditional knowledge, making it more accessible and actionable for modern research.
* **Herb Combination Prediction and Optimisation:** AI models—especially association rule mining and clustering algorithms—analyse historical prescriptions to identify core formula structures (i.e., key herb combinations that frequently appear together), modular patterns based on syndrome types or organ systems and synergistic or antagonistic herb relationships, guiding safer and more effective combinations. This aids the refinement of existing formulas and the generation of new candidate formulas by recombining herbs with shared pharmacological or therapeutic profiles.
* **Network Pharmacology and Multi-Target Mapping:** AI enables multidimensional mapping of herb–compound–target–disease relationships by integrating the chemical composition of herbs, biological targets (e.g., enzymes, receptors, genes), and disease-related pathways. Through network pharmacology, AI helps identify which combinations of herbs affect common molecular pathways, aligning with TCM’s holistic, multi-target therapeutic philosophy.
* **Personalised Formula Design:** With access to individual patient data, such as tongue/pulse diagnosis, symptoms, lab results, and genetic markers, AI can tailor herbal prescriptions to the person’s unique constitution and condition. Algorithms evaluate herb suitability based on pharmacogenomics and allergies, historical outcomes for patients with similar profiles and recommended modifications to classical formulas to suit modern presentations. This enables the development of personalised herbal prescriptions aligned with TCM principles and precision medicine.
* **Virtual Screening and Formula Simulation:** AI simulates how potential formulas behave in the body using in silico pharmacokinetic modelling (absorption, distribution, metabolism, excretion), toxicity screening, herb–drug interaction prediction, and target binding affinity simulation, particularly for chronic or systemic diseases. These simulations reduce trial-and-error in clinical practice and help prioritise formulas for experimental validation or clinical trials.
* **Formula Validation and Efficacy Prediction:** AI tools like supervised machine learning models (e.g., random forests, support vector machines) analyse past clinical outcomes to predict the efficacy of candidate formulas, identify which patient populations are most likely to benefit and recommend dosage adjustments or co-therapies. This enhances evidence-based validation of new or modified TCM formulas.

AI supports TCM formula discovery by mining and structuring historical and clinical data, discovering new herb combinations through pattern recognition, mapping multi-target therapeutic pathways, designing personalised, effective prescriptions, simulating pharmacokinetics, and predicting efficacy. By combining classical wisdom with cutting-edge computational tools, AI paves the way for the next generation of TCM formulas that are scientifically grounded, patient-specific, and globally applicable.

## Chapter 19: Chemical Analysis

Artificial Intelligence (AI) is revolutionising chemical analysis within Traditional Chinese Medicine (TCM), driving advancements in drug discovery, ingredient profiling, and understanding pharmacological mechanisms. The inherent complexity of TCM formulas—often comprising multiple bioactive compounds with synergistic effects—necessitates sophisticated analytical tools. AI is uniquely equipped to address this challenge, especially through machine learning (ML) and deep learning (DL) algorithms.

* **Big Data Processing and Pattern Discovery:** AI models process vast and diverse datasets from TCM chemical databases, enabling complex querying of herbal compounds, data visualisation of molecular interactions and interactive analysis platforms for researchers and clinicians. Natural Language Processing (NLP) is also employed to extract chemical and pharmacological information from classical texts and modern literature, turning unstructured data into structured, actionable knowledge.
* **Predicting Pharmacological Activity:** Machine learning algorithms are trained to predict the biological activity of compounds based on chemical structure, functional groups, and molecular fingerprints. This helps discover new therapeutic agents, understand the mechanisms behind multi-component TCM formulas and identify active ingredients responsible for clinical efficacy. Such models refine TCM understanding from empirical observation to evidence-based pharmacology.
* **Mapping Compound-Biological Relationships:** AI tools enable researchers to establish compound-target-pathway relationships by integrating chemical, genomic, and clinical data. Empowered by AI, network pharmacology models clarify how different compounds in herbal mixtures influence multiple biological targets, reflecting the holistic and multi-targeted nature of TCM.
* **Drug Interaction and Safety Prediction:** AI predicts drug-drug interactions (DDIs), including interactions between TCM herbs and pharmaceuticals. AI can model drug-drug and herb-drug interactions, drug-food and drug-microbiome effects, and genetic factors affecting metabolism using large datasets and deep learning algorithms. This is particularly important in TCM, where complex polyherbal prescriptions can pose interaction risks. AI mitigates these risks by predicting incompatibilities, enhancing safety and treatment outcomes.
* **Enhanced Drug Discovery:** AI accelerates the screening and development of novel compounds derived from TCM by identifying correlations between chemical structure and bioactivity. These models suggest promising lead compounds for further pharmacological testing, reducing the time and cost of traditional drug discovery.
* **Model Fusion for Deeper Insight:** Combining AI methods, such as convolutional neural networks (CNNs), decision trees, and ensemble models, creates more robust, accurate frameworks for analysing chemical interactions in TCM. These hybrid approaches allow for better handling of noisy, imbalanced, or incomplete data, often found in herbal medicine research.

AI is reshaping TCM's chemical analysis landscape by making it more data-driven, predictive, and mechanistically informed. Its ability to model complex chemical interactions, predict therapeutic efficacy, and identify potential safety issues is essential in modernising herbal medicine. Ultimately, AI empowers TCM to move from traditional formulations to precision phytotherapy, where treatments are safer, more effective, and tailored to individual patient needs.

### FordNet

FordNet is an advanced AI-based platform designed to enhance the accuracy and efficacy of Traditional Chinese Medicine (TCM) formulations. By integrating phenotypic (observable traits and treatment outcomes) and molecular (chemical and biological) information, FordNet provides intelligent, data-driven recommendations for herbal combinations. This significantly improves formulation hit rates, optimises compatibility, and increases the precision of therapeutic targeting.

At the core of FordNet is its ability to combine cutting-edge analytical techniques, such as liquid chromatography and mass spectrometry, with AI-powered data processing. This fusion enables the system to:

* Characterise herbal compounds at a detailed molecular level.
* Map bioactive compounds to specific phenotypic outcomes.
* Predict synergistic effects between herbal components.
* Refine dosage and compatibility for individualised prescriptions.

FordNet provides a comprehensive chemical profile of herbal formulations through this integrated approach, uncovering the pharmacological basis of TCM therapies. It improves quality control by identifying and quantifying active ingredients and ensures that formulations are traditionally valid and scientifically substantiated. Additionally, FordNet supports formulation optimisation by suggesting modifications based on patient response patterns and real-time clinical feedback. This aligns with the broader trend of personalised medicine in TCM, where treatments are increasingly tailored to an individual’s constitution, symptoms, and underlying imbalances.

FordNet exemplifies how AI technologies can revolutionise TCM by transforming empirical knowledge into quantifiable, evidence-based practices. It bridges traditional wisdom with modern analytical science, enabling practitioners to deliver safer, more effective, highly personalised herbal treatments grounded in classical theory and molecular precision.

### Data Fusion Techniques in TCM Research

Data fusion techniques are crucial in advancing Traditional Chinese Medicine (TCM) research. They integrate information from multiple analytical sources—such as spectroscopy, chromatography, mass spectrometry, and metabolomics—to construct a more holistic and accurate understanding of TCM formulations.

Rather than relying on a single dataset or method, data fusion combines complementary datasets at various levels:

* Low-level fusion merges raw data from different instruments.
* Mid-level fusion integrates features or patterns extracted from each dataset.
* High-level fusion combines decision outputs or interpretation results to strengthen final predictions.

By synthesising diverse types of chemical, biological, and clinical data, this approach enables researchers to identify complex interactions between multiple herbal compounds, detect bioactive constituents with greater sensitivity and specificity, predict synergistic effects or potential contraindications and enhance the mechanistic understanding of traditional formulations.

In AI and machine learning, data fusion significantly improves model training and predictive accuracy, creating more robust algorithms for drug discovery, syndrome differentiation, and personalised treatment recommendations. Ultimately, data fusion promotes a systems-level approach to TCM—mirroring the holistic philosophy of Chinese medicine—while offering a rigorous scientific foundation for modern research, innovation, and global integration.

## Chapter 20: Drug Discovery and Development in TCM

Traditional Chinese Medicine (TCM) represents a vast reservoir of natural compounds with therapeutic potential. From thousands of clinical uses, TCM includes many botanical, mineral, and animal-derived ingredients that inspire modern pharmacological research. Between 1981 and 2019, more than 60% of FDA-approved small-molecule drugs were either derived from or inspired by natural products, underscoring the relevance of TCM as a valuable source for drug discovery (Song, Chen, & Chen, 2024).

As the complexity of modern diseases increases, there is a growing demand for novel therapeutic agents with multitarget actions and lower side effect profiles—characteristics often found in traditional herbal formulations. Artificial intelligence (AI) is revolutionising this landscape by enhancing how bioactive compounds are identified, characterised, and translated into viable clinical treatments.

* **Accelerated Compound Screening and Identification**: AI can process massive chemical datasets derived from TCM herbs, particularly through deep learning and machine learning algorithms. These models rapidly analyse chemical structures and identify novel active compounds, classify herbal constituents based on therapeutic potential, and reduce the time and cost of early-stage research by automating the screening process. Using high-throughput virtual screening (HTVS), AI can evaluate thousands of molecules against disease-specific targets in silico, prioritising those with the highest likelihood of efficacy for experimental validation.
* **Mechanism Elucidation and Target Prediction**: AI models play a key role in predicting the molecular targets of TCM components. This involves mapping compound-target-pathway networks, simulating ligand–receptor interactions, and identifying multi-target synergies—a hallmark of TCM formulations. These capabilities help researchers uncover the pharmacodynamic mechanisms behind traditional prescriptions, offering a bridge between empirical knowledge and scientific validation.
* **Validation and Pharmacological Modelling:** Once potential targets are identified, AI assists in bioinformatics analysis to confirm the biological relevance of targets, omics data integration (genomics, proteomics, metabolomics) to understand compound impact at a systems level and supporting experimental studies by narrowing focus to the most promising compound–target interactions. This data-driven prioritisation enhances efficiency and resource allocation in wet-lab experiments.
* **Predictive Toxicology and Safety Profiling**: AI algorithms can also predict toxicity profiles of novel compounds, herb-drug interactions and potential adverse effects based on structure-activity relationships (SAR). This is especially important in TCM, where complex multi-herb formulas may pose risks if not accurately assessed. Early detection of potential safety concerns reduces the likelihood of clinical trial failures and improves patient safety.
* **Integration with TCM Databases and Knowledge Graphs**: Advanced AI systems increasingly leverage knowledge graphs and semantic networks built from curated TCM databases. These platforms synthesise data from classical texts, pharmacopoeias, clinical case reports and experimental pharmacology. Integrating traditional wisdom with modern datasets allows AI to propose novel combinations or scientifically grounded reformulations consistent with TCM principles.

By combining ancient herbal wisdom with cutting-edge technology, AI is unlocking the full potential of TCM in drug discovery. It enables a systematic, data-driven, and personalised approach to identifying, evaluating, and validating herbal compounds for modern clinical use. This transformation not only accelerates the development of new, safe, and effective medicines but also reinforces the scientific credibility of TCM in global pharmaceutical research. As the field evolves, the integration of AI into TCM drug discovery promises to deliver innovative therapeutic solutions aligned with the holistic and preventative ethos of traditional Chinese medicine.

### AlphaFold3

AlphaFold3 is the latest advancement in protein structure prediction developed by DeepMind in collaboration with Isomorphic Labs. Building upon the revolutionary success of AlphaFold2, which accurately predicted 3D protein structures from amino acid sequences, AlphaFold3 extends these capabilities even further. It not only model’s proteins but also protein–nucleic acid, protein–ligand, and protein–ion interactions, offering a holistic view of complex biomolecular systems. This marks a major leap in the precision and scope of computational biology.

Integrating AlphaFold3 into TCM research is poised to accelerate the modernisation of herbal medicine and drug discovery by offering detailed insights into how natural compounds interact with biological targets at the molecular level.

* **Accelerating Drug Discovery from Herbal Compounds**: TCM formulations often involve bioactive compounds whose mechanisms of action are not fully understood. AlphaFold3 enables researchers to predict the protein targets of herbal ingredients, model ligand–protein interactions between TCM compounds and human proteins, and identify multi-target binding profiles, aligning with the holistic, multi-pathway nature of TCM. This supports the rational development of TCM-based drugs with improved precision, efficacy, and safety.
* **Optimising Formula Design and Synergistic Combinations**: Many TCM formulas involve multiple herbs working synergistically. AlphaFold3 allows for in silico simulation of compound-compound-protein networks, identification of synergistic effects based on shared or complementary protein targets and elimination of potential antagonistic interactions at the molecular level. This enhances formula refinement, leading to more effective and scientifically validated treatments.
* **Elucidating Mechanisms of Action**: One of the challenges in integrating TCM with modern science has been the lack of mechanistic clarity. AlphaFold3 provides high-resolution predictions of how specific herbal compounds interact with disease-related proteins, which modulate metabolic, inflammatory, or immunological pathways and how personalised treatment might be adjusted based on an individual’s molecular profile. This bridges the gap between traditional empirical knowledge and modern biochemical understanding.
* **Supporting Safety and Toxicology Studies**: Predicting off-target effects and potential toxicities is essential for clinical application. AlphaFold3 can identify unintended protein binding by TCM compounds, support AI-driven screening for toxicity, allergenicity, and cross-reactivity and enhance the safety profile of complex herbal formulas.

AlphaFold3 represents a groundbreaking tool in translational TCM research, offering molecular-level insights that align well with traditional herbal therapies' multi-component, multi-target nature. By integrating this technology into TCM formulas' research, validation, and optimisation, researchers can modernise practices without losing their holistic roots. Its application marks a new era where ancient wisdom meets molecular precision, allowing TCM to participate more fully in global biomedical innovation and evidence-based drug development.

### Toxicity and Side Effects

Artificial Intelligence (AI) plays a pivotal role in enhancing the safety profile of Traditional Chinese Medicine (TCM) by predicting toxicity and adverse effects of herbal components. One of the major challenges in TCM drug development lies in the complex interactions among the multi-component formulas, where unintended side effects or toxic compounds may go undetected using traditional methods alone.

AI models—particularly machine learning (ML) and deep learning (DL) architectures—can process vast, multidimensional datasets from clinical records, pharmacological studies, molecular databases, and toxicological research. These models are trained to identify patterns and correlations between chemical structures and known toxic outcomes, allowing them to:

* Predict potential toxicological risks before clinical trials.
* Flag herb-drug interactions in polypharmacy settings.
* Evaluate the dose-dependent safety profiles of individual herbs or formulas.
* Recommend safer substitutes or adjustments in formulation.

By simulating thousands of interactions, AI helps practitioners and researchers avoid late-stage failures in drug development and improve clinical decision-making. These predictive insights are especially valuable for vulnerable populations such as the elderly, pregnant individuals, or those with chronic illnesses who may be more susceptible to adverse effects. Ultimately, AI-driven toxicity prediction advances the modernisation of TCM by ensuring that safety assessments are evidence-based, proactive, and scalable, aligning TCM practices with global pharmacovigilance and regulatory standards.

### Drug-Drug Interactions

Drug-drug interactions (DDIs) are vital considerations in clinical practice, ensuring patient safety when multiple substances are used concurrently. In Traditional Chinese Medicine (TCM), herbal formulations often consist of complex combinations of various ingredients, and the risk of interactions, either with other herbs or with pharmaceutical drugs, is significantly heightened. The TCM principle of "incompatibility" (面相) has long acknowledged that certain herbal combinations may lead to adverse effects or diminished efficacy, necessitating a more precise and predictive approach to formulation.

As TCM becomes increasingly integrated with modern healthcare systems, understanding and predicting DDIs have become essential to mitigate potential risks. However, herbal medicine's holistic and synergistic nature presents challenges for conventional reductionist analysis. Modern technologies, particularly AI-enabled systems pharmacology, offer transformative solutions. These tools identify bioactive compounds within herbal formulations, predict molecular targets and pathways, clarify interaction mechanisms with pharmaceutical agents or other herbs and model complex networks of interactions using computational simulations. By integrating network pharmacology, machine learning, and large-scale molecular databases, AI systems can uncover known and previously hidden DDIs, offering a systematic, data-driven approach to TCM safety evaluation. These models simulate interactions in silico before clinical use, allowing for risk stratification of herbal combinations, optimised prescription recommendations and alerts for contraindications or potential toxicities.

This approach is especially valuable in personalised medicine, where patients may take herbal and Western pharmaceuticals. AI-enabled DDI prediction ensures greater clinical precision and fewer adverse reactions and contributes to TCM practices' global modernisation and regulatory integration.

### Herbal-Drug Interactions (HDI)

As Traditional Chinese Medicine (TCM) becomes increasingly integrated with Western biomedical practices, the complexity of herbal-drug interactions (HDIs) emerges as a critical concern. TCM formulations typically comprise multiple herbs, each containing numerous active compounds that can interact unpredictably with synthetic pharmaceutical drugs. These interactions may enhance or inhibit drug efficacy or trigger harmful side effects. The intricacy and variability of such interactions have traditionally posed a significant barrier to safe and effective integrative healthcare.

Recent advancements in AI and the development of comprehensive HDI databases are helping to overcome these challenges. Machine learning algorithms—especially those trained on large datasets of clinical records, chemical structures, metabolic pathways, and pharmacokinetic profiles—can predict potential herb-drug interactions with increasing accuracy. These AI-powered models:

* Analyse patterns in known HDI cases
* Simulate chemical and biological interactions.
* Forecast risks of toxicity, reduced efficacy, or synergistic effects.
* Support clinical decision-making for safer prescription practices.

Compiling structured databases—integrating TCM pharmacopoeias, pharmaceutical drug libraries, chemical component libraries, and biomedical pathway maps—provides the foundational data infrastructure. These resources allow AI systems to cross-reference traditional herbal knowledge with modern pharmacological science, enhancing diagnostic precision and patient safety.

AI-based HDI models enable real-time interaction screening, customised alerts, and automated compatibility checks. They are essential tools for practitioners operating at the intersection of Chinese and Western medicine. They pave the way for a more predictive, personalised, and safe approach to integrative healthcare.

### The PHYDGI Database

The PHYDGI (Phytochemical–Drug–Gene Interaction) Database is a specialised resource to address the increasing need for evidence-based herbal-drug interactions (HDIs) management. It integrates complex HDI data into a well-structured, scientifically validated format with citations to peer-reviewed studies and pharmacological literature. This database catalogues a wide array of herbal entries, each annotated with:

* Interaction strength levels (e.g. mild, moderate, severe)
* Mechanistic classifications (e.g. pharmacokinetic vs. pharmacodynamic)
* CYP enzyme involvement, transporter systems, and receptor pathways
* Associated clinical risks and documented outcomes.

By consolidating this information into an accessible platform, PHYDGI empowers stakeholders—including health practitioners, TCM clinicians, naturopaths, botanical medicine specialists, and food supplement manufacturers—to make more informed and safer prescribing decisions. Crucially, PHYDGI enhances safety by identifying and mitigating high-risk herb-drug combinations, supporting the development of safer botanical formulations, and promoting the rational, evidence-informed integration of TCM herbs and Western pharmaceuticals.

In the broader context of AI-assisted integrative medicine, PHYDGI serves as a core database that can be linked with machine learning models to enhance the prediction of adverse interactions and assist in real-time clinical decision-making. It represents a significant step toward standardising herbal-drug interaction data, advancing patient safety, and supporting the global modernisation of TCM and complementary therapies.

### Hybrid Decision Support System

Martins et al. developed a novel hybrid decision support system (DSS) specifically designed to identify potential herb-drug interactions (HDIs) by integrating artificial intelligence (AI) technologies with pharmacological and botanical data. This system represents a significant step toward enhancing patient safety in integrative medicine, where Traditional Chinese Medicine (TCM) and Western pharmaceuticals are often used concurrently.

The hybrid DSS leverages machine learning algorithms and knowledge-based inference engines to predict new and previously unreported HDIs, cross-reference known pharmacokinetic and pharmacodynamic pathways and assess potential risk levels based on dosage, compound interaction profiles, and patient variables. By analysing vast datasets of clinical cases, pharmacological records, and known toxicological patterns, the system supports clinicians, pharmacists, and herbal medicine practitioners in making better-informed and safer treatment decisions. It not only reduces the risk of adverse drug events (ADEs) but also helps tailor therapy by accounting for individual patient profiles and known compatibilities.

This AI-enhanced approach brings greater precision, speed, and adaptability to a field traditionally reliant on empirical knowledge and manual cross-checking. As the integration of AI into TCM advances, systems like the one proposed by Martins et al. pave the way for a new era of intelligent, data-driven clinical decision support, ensuring the safe and effective co-use of herbs and conventional medicines.

## Chapter 21: AI-Enhanced Network Pharmacology

Network pharmacology represents a paradigm shift in drug discovery and formulation development, especially within Traditional Chinese Medicine (TCM). It moves beyond the classical “single-drug, single-target” approach and embraces a “multi-component, multi-target” framework, which is inherently aligned with TCM's holistic nature. This systems-level perspective is particularly suited for treating complex, multifactorial diseases involving multiple physiological systems.

AI-enhanced network pharmacology brings powerful computational tools to this field, enabling the rapid analysis, prediction, and visualisation of compound-target-pathway-disease relationships. The Mechanism of AI-Enhanced Network Pharmacology in TCM includes:

1. **Data Acquisition and Preprocessing**: AI tools collect and clean high-volume data from TCM databases (e.g., TCMSP, TCMID, BATMAN-TCM), chemical structure databases, omics datasets (genomics, proteomics, metabolomics) and clinical records and biomedical literature. Natural language processing (NLP) extracts semantic and clinical meaning from unstructured texts, such as classical texts and case reports.
2. **Compound Screening and Active Ingredient Identification**: Machine learning algorithms (e.g., Random Forest, Support Vector Machines, Graph Neural Networks) predict and classify bioactive compounds based on ADME (absorption, distribution, metabolism, excretion) properties. Deep learning filters out ineffective compounds, identifying those with high drug-likeness and therapeutic relevance.
3. **Target Prediction and Validation**: AI models (e.g., DeepDTI, DeepConv-DTI) accurately predict compound-target interactions. AI–enhanced structure–activity relationship (SAR) models infer the biological relevance of molecular structures. Predictions are validated through molecular docking simulations and experimental data cross-referencing.
4. **Construction of Compound-Target-Pathway-Disease Networks**: Identified ingredients and targets are embedded into multi-layered pharmacological networks, where nodes represent compounds, genes/proteins, pathways, or diseases and edges represent known or predicted interactions. AI clustering and centrality analysis identify key hub targets, synergistic compound groups, and potential biomarkers.
5. **Mechanism Elucidation and Therapeutic Optimisation**: These networks are mined to reveal pathway enrichment (e.g., inflammation, apoptosis, immune regulation), mechanisms of synergy across herbs or ingredients and potential side effects or contraindication. AI evaluates combinations to recommend synergistic multi-herb formulations that optimise efficacy and safety.
6. **Feedback Loop for Iterative Refinement**: Clinical and experimental feedback is fed back into the AI model to refine predictions, improve robustness of the pharmacological network and personalise treatment recommendations based on patient-specific data.

A typical AI-enhanced network pharmacology workflow in TCM might involve selecting a classic TCM formula for rheumatoid arthritis, using AI to screen and predict the active ingredients in each herb, mapping each compound to immune-regulation pathways (e.g., IL-6, TNF-α), identifying shared targets between herbs that enhance anti-inflammatory effects and recommending formula modifications to reduce toxicity while preserving efficacy.

AI-enhanced network pharmacology is revolutionising TCM research by enabling the systematic elucidation of therapeutic mechanisms, accelerating multi-target drug discovery, and paving the way for precision herbal formulations. This integration makes TCM increasingly evidence-based, mechanistically understood, and globally scalable.

### Drug Target Networks

Drug-target networks are critical to understanding how TCM compounds interact with biological systems. These networks map the interactions between bioactive components in herbal formulations and their corresponding molecular targets, such as enzymes, receptors, or signalling proteins. By constructing and analysing these networks, researchers can uncover the synergistic effects inherent in many TCM prescriptions, where multiple ingredients act on complementary pathways to enhance efficacy or reduce toxicity.

This network-based approach enables a systems-level view of how TCM formulations influence biological pathways, offering insights into the mechanisms of action behind traditional remedies. For example, a single herbal compound might influence inflammatory, immune, and metabolic pathways simultaneously—an effect that would be difficult to isolate without the visual and computational clarity offered by drug-target mapping. Moreover, by integrating drug-target networks with clinical data and disease models, researchers can predict the therapeutic relevance of new herbal combinations, optimise existing formulas for specific syndromes or disease profiles, minimise potential side effects or drug interactions and support personalised TCM treatment strategies.

As AI continues to enhance the construction and analysis of these networks, especially through deep learning and graph-based models, the field moves closer to precision herbal medicine, where treatments are scientifically validated, systematically designed, and tailored to individual biological responses.

### Disease-Gene-Drug Networks

Disease-gene-drug networks are powerful tools that integrate genetic, pharmacological, and pathological data to uncover the intricate relationships between disease mechanisms, genetic factors, and therapeutic compounds. Within the context of Traditional Chinese Medicine (TCM), these networks enable researchers to explore how herbal formulations, and active compounds influence the underlying genetic causes of disease.

By mapping connections between specific genes associated with diseases and the bioactive ingredients found in TCM, this integrative approach offers several key advantages:

* **Identification of Genetic Targets**: AI-driven network pharmacology helps pinpoint genes central to disease progression. TCM compounds interacting with these genes or their products can be prioritised for further investigation.
* **Mechanistic Insights**: These networks reveal how certain herbs may modulate genetic expression, protein activity, or signalling pathways, providing a scientific rationale for traditional remedies.
* **Targeted Drug Discovery**: By integrating genomics and phytochemistry, researchers can discover or design new TCM-based treatments for specific gene-related pathologies, including chronic and complex diseases such as cancer, autoimmune disorders, and neurological conditions.
* **Personalised Therapy Development**: Disease-gene-drug networks pave the way for precision TCM, allowing herbal prescriptions to be tailored based on a patient’s genetic profile and disease subtype.

Ultimately, by bridging ancient herbal wisdom with modern molecular biology and AI analytics, disease-gene-drug networks elevate TCM to a new level of therapeutic relevance, where treatments are holistic, genetically informed, evidence-based, and clinically adaptive.

### Network Analysis

The application of Artificial Intelligence (AI) in network pharmacology significantly enhances our ability to decode the complex, multi-component, and multi-target nature of Traditional Chinese Medicine (TCM). One of the most transformative roles of AI lies in its ability to perform network analysis. This process maps and interprets the intricate interactions between herbal compounds, target genes, proteins, and metabolic pathways. AI leverages advanced algorithms and computational techniques such as:

* **Node Importance Evaluation**: AI identifies key nodes—genes, proteins, or compounds—that play pivotal roles in disease modulation or treatment efficacy. These “hub nodes” are often critical targets for TCM compounds and may reveal the main therapeutic levers within a network.
* **Network Module Identification**: AI isolates functional modules or sub-networks—clusters of tightly connected elements within the larger pharmacological network. These modules often represent biologically meaningful groupings such as pathways involved in inflammation, immune regulation, or metabolic balance, aligning closely with TCM treatment principles.
* **Synergistic Mechanism Discovery**: By analysing the topological and functional relationships within the network, AI can uncover synergistic interactions between multiple herbs or compounds in a formula. This aligns with TCM's core concept of multi-component harmony, where the therapeutic effect arises from the balanced interplay of several ingredients, not a single active compound.

These AI-enhanced techniques support the construction of layered, dynamic pharmacological networks that map compound-target relationships and downstream effects on biological pathways and gene expression. By understanding how individual herbal components interact within the broader biological system, researchers can better predict therapeutic outcomes, minimise side effects, and refine TCM formulations for greater clinical efficacy.

In short, AI-driven network analysis transforms TCM from a traditionally empirical practice into a data-driven, systems-level science. It offers insights into the hidden architecture of healing mechanisms and bridges the gap between classical wisdom and modern biomedical research.

## AI In Herbal Medicine: A Brief Summary

Artificial Intelligence (AI) is revolutionising Traditional Chinese Medicine (TCM) herbal practice by bringing precision, efficiency, and scientific rigour to its ancient foundations. Through machine learning, deep learning, and advanced data analytics, AI is enabling:

* **Herb Identification and Classification**: AI recognises and classifies herbs based on chemical, botanical, and morphological features, improving quality control, standardisation, and authenticity verification.
* **Chemical Component Analysis**: AI rapidly analyses complex herbal compounds, predicting pharmacological activity, toxicity, and interactions. It supports compound profiling, quality assessment, and ingredient discovery.
* **TCM Formula Discovery**: AI models mine large TCM databases to identify novel herbal combinations, optimise classical formulas, and predict multi-target mechanisms using network pharmacology.
* **Personalised Prescriptions**: AI analyses individual patient data—symptoms, constitution, lifestyle, and biometrics—to recommend tailored herbal prescriptions, enhancing efficacy and safety.
* **Drug Discovery and Development**: AI accelerates the identification of bioactive compounds, predicts their targets, and models interactions. This supports high-throughput screening, and the discovery of new therapeutics derived from TCM.
* **Safety and Interactions**: AI predicts herb-drug and herb-herb interactions (HDIs/DDIs), reducing the risk of adverse effects and improving integration with Western medicine.
* **Network Pharmacology**: AI-powered network analysis reveals how herbs act across multiple biological targets and pathways, providing a systems-level view of their synergistic mechanisms and therapeutic potential.

These innovations are ushering in a new era of evidence-based, personalised, and globally relevant herbal medicine, aligning TCM with modern science while preserving its holistic principles. Through integrating AI and big data analytics, TCM is being modernised, enabling deeper insights into its foundational principles and bridging the gap between ancient wisdom and modern biomedical sciences. This fusion enhances the personalisation and precision of TCM-based therapies and sets the stage for a new era of holistic, data-driven healthcare.

# PART 4: Acupuncture

Acupuncture is one of the most internationally recognised and widely practised components of Traditional Chinese Medicine (TCM). With a documented history spanning over 3,000 years in China, acupuncture involves the insertion of fine, hair-thin needles into specific points on the body, known as acupoints, to stimulate the flow of **qi** (vital energy) along the meridians. It aims to restore energetic balance and promote physiological harmony within the body. Acupuncture has been shown to have therapeutic value in a broad range of health conditions, including chronic pain, anxiety, depression, gastrointestinal disorders, infertility, and post-stroke rehabilitation.

In the 21st century, acupuncture is undergoing a digital transformation, largely driven by artificial intelligence (AI) advances. Integrating AI into acupuncture enhances diagnostic accuracy and treatment precision and revolutionises education, feedback mechanisms, and patient engagement. AI Applications in Acupuncture Practice include:

1. **Diagnosis and Point Selection**: AI algorithms analyse patient data, including symptom patterns, pulse data, tongue images, and medical history, to identify optimal acupoints for treatment. Models such as BiLSTM, Transformer networks, and knowledge graphs enable syndrome differentiation with greater accuracy, enhancing point selection for targeted therapeutic outcomes. These tools support dynamic treatment planning, with acupoints adjusted in real time based on symptom evolution or biofeedback signals.
2. **Personalised Treatment Planning**: AI systems tailor acupuncture prescriptions by considering an individual’s constitution, lifestyle, current symptoms, and past responses to treatment. This precision level ensures treatments are more effective, safer, and better tolerated, particularly in complex or chronic conditions.
3. **Real-Time Monitoring and Biofeedback Integration**: Wearable devices and biosensors are now being used with AI to monitor real-time patient responses to acupuncture. Metrics such as heart rate variability (HRV), skin conductance, muscle tone, and respiration patterns can provide immediate feedback to the practitioner—or even an AI system—that adjusts stimulation parameters accordingly. This approach supports **closed-loop acupuncture systems**, increasing treatment safety and effectiveness.
4. **Outcome Tracking and Data Analytics**: Digital records supported by AI allow for continuous tracking of patient progress across sessions. By compiling and analysing large amounts of clinical outcome data, AI tools can assess treatment efficacy, forecast therapeutic trajectories, and suggest course corrections, creating an evidence-informed feedback loop.
5. **Education and Simulation**: AI transforms acupuncture education by providing realistic virtual patient simulations and interactive training platforms. Intelligent tutoring systems can evaluate students' acupoint selection, technique, and diagnostic reasoning. Adaptive learning systems adjust content based on learner performance, guiding practitioners toward mastery through personalised feedback and scenario-based learning.
6. **Research and Standardisation**: AI is used to analyse large datasets from clinical trials and historical acupuncture records to establish standardised protocols, validate point indications, and map new clinical correlations. This contributes to a more evidence-based framework for acupuncture practice, enhancing its credibility within integrative and biomedical care systems.

As AI technologies evolve, their integration into acupuncture is expected to deepen. Future developments may include robotic-assisted needling systems for consistent and precise insertion, remote-controlled devices for tele-acupuncture, and fully integrated platforms combining AI-based diagnosis with automated point stimulation (laser or electroacupuncture).

Importantly, while AI offers powerful tools for enhancing the efficacy and reach of acupuncture, it is intended to support—rather than replace—the trained acupuncture practitioner's skill, intuition, and relational sensitivity. The convergence of AI and acupuncture thus represents a symbiosis of ancient wisdom and modern intelligence, offering a more personalised, data-informed, and accessible model of care for the global population.

## Chapter 22: AI-Directed Acupuncture

AI-Guided Acupuncture is applying artificial intelligence (AI) technologies to support or automate key aspects of acupuncture practice. It integrates traditional Chinese Medicine (TCM) knowledge with modern tools such as machine learning, data analytics, robotics, and sensor technologies. The goal is to enhance the precision, personalisation, and consistency of acupuncture treatments. Core functions of AI-guided acupuncture include:

* **Acupoint Selection:** AI models analyse clinical data, such as symptoms, tongue images, pulse signals, and patient history, to recommend the most effective acupoint combinations.
* **Diagnosis Support:** AI assists in syndrome differentiation by recognising complex symptom patterns and correlating them with established TCM diagnostic frameworks.
* **Real-Time Feedback:** Wearable sensors and biofeedback tools measure patient responses (e.g., heart rate variability, skin resistance), enabling dynamic adjustments to treatment parameters.
* **Robotic Assistance:** In research and emerging clinical settings, robotic arms and guided devices deliver precise needling or non-invasive stimulation, particularly for remote care or standardised protocols.

By combining ancient wisdom with modern intelligence, AI-guided acupuncture represents a promising evolution in integrative medicine. It preserves TCM's holistic approach while bringing greater objectivity, reproducibility, and global scalability to the practice.

**Traditional vs. AI-Guided Acupuncture**

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| --- | --- | --- |
| Aspect | Traditional Acupuncture | AI-Guided Acupuncture |
| Diagnosis | Based on the practitioner’s training, intuition, and observation (tongue, pulse, symptoms) | Augments diagnosis using AI-analysed images, symptom input, and biosensors |
| Point Selection | Drawn from classical theory, personal experience, and case-by-case judgment | Optimised through pattern recognition, case databases, and predictive algorithms |
| Customisation | Tailored to the individual's constitution and syndrome pattern | Hyper-personalised using large datasets and adaptive learning |
| Tools & Technology | Needles, moxa, cupping, electrostimulation | May include cameras, sensors, wearables, robotic arms, electroacupuncture systems |
| Needle Application | The practitioner’s feel decides manual insertion, depth, and angle | Automated or assisted insertion based on anatomical mapping and sensors |
| Feedback Monitoring | Based on the patient’s verbal feedback, pulse changes, or facial cues | Real-time monitoring using HRV, EMG, skin temperature, or AI feedback loops |
| Learning & Adaptation | Based on practitioners’ clinical experience over time | Machine learning continuously refines protocols across populations |
| Time Efficiency | Variable, depending on the practitioner’s experience | Can be faster due to real-time suggestions and automation |
| Scope of Application | Broad and holistic, rooted in classical TCM theory | Often focused on specific use cases (pain, anxiety, digestion) initially |
| Educational Use | Relies on apprenticeship and classical texts | Includes simulations, point logic tutors, and interactive AI training tools |
| Limitations | Subjective quality depends on practitioner skill | May oversimplify or misinterpret complex syndromes if the data is limited |
| Practitioner Role | Central — guides diagnosis, treatment, and the healing process | Still central — AI is an assistant, not a replacement |

## Acupoint Selection and Prescription

Acupoint selection and prescription form the foundation of effective acupuncture treatment. Traditionally, practitioners determine the optimal acupoints—among the 361 points distributed across 14 meridians—based on syndrome differentiation gathered through TCM’s four diagnostic methods (inspection, listening/smelling, inquiry, and palpation). The process involves choosing primary points based on the patient’s condition and constructing a prescription of point combinations tailored to the individual. Despite centuries of practice, there remains a lack of standardised protocols for acupoint selection across many diseases. This gap has created an opportunity for artificial intelligence (AI) to support and advance acupuncture practice.

AI-directed acupuncture leverages data mining techniques and machine learning algorithms to analyse vast and often complex clinical datasets. With access to increasingly comprehensive TCM databases, AI can uncover patterns and associations between diseases and acupoint usage that may not be immediately apparent through traditional analysis. Unsupervised learning methods—particularly association rule mining (such as the Apriori algorithm) and clustering techniques—have proven especially useful in identifying acupoint groupings, frequency patterns, and efficacy correlations. These AI tools digitise and quantify treatment knowledge, making it possible to:

* Generate evidence-based recommendations for acupoint prescriptions.
* Reveal novel acupoint combinations for emerging conditions.
* Inform the development of standardised protocols for clinical use.
* Advance the theoretical understanding of acupuncture by discovering latent knowledge hidden within historical and modern treatment data.

AI-directed acupoint selection and prescription play a transformative role in modernising acupuncture. They offer more objective, consistent, and evidence-based approaches while still being rooted in the holistic principles of Traditional Chinese Medicine.

## Acupuncture Manipulation

Acupuncture manipulation refers to the deliberate twirling, rotating, and lifting-thrusting movements of acupuncture needles at specific acupoints, performed with precise control over depth, strength, frequency, and direction. These manual techniques are essential to stimulating qi and achieving therapeutic effects. However, variations in nerve excitability, tissue resistance, and temperature across different acupoints make consistent, effective manipulation challenging, highlighting the need for quantification and standardisation.

Recent advances in AI and sensor technologies have led to significant breakthroughs in quantifying and classifying acupuncture manipulation. Instruments now exist that can accurately measure the biomechanical parameters of needling techniques. Based on these measurements, a standardised TCM acupuncture manipulation database has been established, enabling the development of objective models that mimic traditional manual methods. One major advancement includes using self-organising neural network feature maps to develop classification models for lifting-thrusting manipulation. These AI models facilitate the differentiation between various manipulation types, such as reinforcing or reducing by twirling or rotating and reinforcing or reducing by lifting and thrusting. Additionally, computer vision systems integrated with convolutional neural networks (CNNs) and long short-term memory (LSTM) architectures have shown high accuracy in identifying and classifying dynamic needling movements from video input, enabling real-time feedback and precision training.

Other innovative systems incorporate electroencephalogram (EEG) signals to explore the neural response to different manipulation styles, offering new insights into patient reactions and the therapeutic impact of specific techniques. AI-assisted manipulation technologies are now paired with virtual reality (VR) environments for acupuncture training. These immersive systems allow students and junior practitioners to learn and refine manipulation techniques in a risk-free, feedback-driven environment, greatly enhancing the quality and consistency of acupuncture education.

Despite these advancements, challenges remain. Certain tactile parameters—such as the exact force, direction, and depth applied during manipulation—are still difficult to digitise or replicate fully. Ongoing research and developing more sensitive and sophisticated instrumentation are necessary to overcome these limitations.

In the long term, the integration of AI with acupuncture manipulation promises to improve the safety, reproducibility, and efficacy of clinical acupuncture, support the training and certification of practitioners through objective measurement tools and lay the foundation for standardised protocols that preserve the therapeutic essence of traditional techniques while leveraging the precision of modern technology. By bridging traditional craftsmanship with digital precision, AI is pivotal in bringing acupuncture manipulation into the next era of evidence-based practice.

## Acupuncture Efficacy

Artificial Intelligence is increasingly being used to predict the clinical efficacy of acupuncture treatments, offering a transformative approach to personalised and evidence-based Traditional Chinese Medicine. One of the most promising areas in this field is neuroimaging-based efficacy prediction, which uses machine learning algorithms to correlate patient brain imaging data with treatment outcomes.

Researchers have recently explored how neuroimaging combined with machine learning can be a predictive tool for acupuncture response at the individual level. AI models can identify subtle patterns in brain activity that correlate with successful acupuncture treatments by training algorithms on datasets that include pre-treatment neuroimaging and clinical efficacy outcomes.

Among the most widely used algorithms in this domain is the Support Vector Machine (SVM), a supervised learning model that excels in binary classification problems. SVM can be trained to distinguish between likely responders and non-responders based on features extracted from neuroimaging data, such as fMRI or EEG, and clinical indicators. Once trained, this model allows clinicians to input a new patient’s clinical and imaging data and receive a data-driven prediction about the potential success of acupuncture treatment.

This form of AI-assisted decision support empowers practitioners to tailor treatment plans more effectively, improving the likelihood of positive clinical outcomes. It also avoids ineffective interventions, saving patients time and cost. Finally, integrating objective neurobiological evidence with traditional diagnostic frameworks strengthens the scientific basis for acupuncture.

Beyond neuroimaging, AI can also analyse broader clinical datasets—such as symptom reports, physiological signals, and treatment histories—to refine outcome prediction. As these models evolve, they contribute to a feedback-driven loop where each new case improves the system's predictive power. By incorporating AI into the evaluation of acupuncture efficacy, TCM practitioners can move toward a more objective, individualised, and data-informed practice, strengthening acupuncture therapies' credibility and clinical impact.

# PART 5: Robotics

Robotics is a field of engineering and computer science concerned with designing, constructing, operating, and using automated machines capable of performing tasks traditionally carried out by humans. Robotics integrates hardware (mechanical components), software (algorithms and control systems), and often Artificial Intelligence (AI) to enable machines to perceive, decide, and act in dynamic environments.

In traditional Chinese medicine (TCM), robotics, when combined with AI, represents an emerging frontier in modernising clinical practice. Robotic systems are not merely mechanical tools; they are becoming intelligent collaborators capable of supporting precision, consistency, and efficiency in diagnosis and treatment.

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| **Advantages of Robotics in AI-TCM Integration** | **Limitations and Considerations** |
| * **Standardisation**: Robots eliminate variability caused by human fatigue or subjectivity. * **Precision**: Enhanced ability to perform delicate tasks (e.g. needling, sensing pulse) with micrometre accuracy. * **Safety**: Robots can detect anomalies or errors and stop procedures before harm occurs. * **Training**: Robotic systems can simulate patient interaction for educational purposes, helping students refine diagnostic and therapeutic skills in controlled environments. | * **Lack of Intuition**: Robots cannot yet replicate the intuitive and holistic reasoning of experienced practitioners. * **Ethical Concerns**: When robots are involved in care, questions about patient trust, consent, and human connection arise. * **Cost and Accessibility**: High costs may limit widespread adoption, particularly in rural or traditional settings. |

When combined with AI, robotics offers TCM a powerful means of enhancing diagnostic accuracy, procedural safety, and educational quality. While it will not replace TCM practice's intuitive, human-centred nature, it is a valuable partner in the digital transformation field, bridging ancient wisdom with modern technological capability.

## Chapter 23: TCM Bots

TCM bots are intelligent software applications—often powered by Artificial Intelligence (AI) and Natural Language Processing (NLP)—designed to interact with users, provide Traditional Chinese Medicine (TCM) knowledge, and assist with diagnosis, treatment guidance, and education. These bots simulate human conversation and clinical reasoning, making TCM more accessible, interactive, and standardised. Types of TCM Bots and Their Functions include:

* **Diagnostic Assistants:** These bots ask patients questions based on the Four Diagnostic Methods (inspection, listening/smelling, inquiry, and palpation), then use AI models to suggest possible TCM syndromes, recommend acupuncture points or herbal formulas, and provide lifestyle or dietary advice.
* **Educational Bots:** Used by students and practitioners to quiz users on TCM theory (e.g. meridians, Five Elements, Zang-Fu organs), simulate case studies and diagnosis and explain classical texts and formulas (e.g. from *Huangdi Neijing*)
* **Patient-Facing Chatbots:** These help general users understand their constitution (e.g. Qi deficiency, Yin excess), self-care strategies rooted in TCM and preventive healthcare tips.
* **Pharmacy and Formula Bots:** These assist in herbal formula recommendation and adjustment, cross-checking herb compatibility and identifying contraindications or herb-drug interactions.

Many bots use advanced models such as ChatGPT, TCM-GPT, or QiBo, which are pretrained on large TCM corpora including classical texts, clinical records, and modern research.

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| Input Layer | Processing Layer | Output Layer |
| Users input symptoms, medical history, or images (e.g. tongue photos). | AI algorithms (e.g. LLMs, decision trees, or expert systems) interpret the data using embedded TCM knowledge bases. | The bot responds with syndrome differentiation, treatment advice, or educational content. |

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| **Benefits** | **Limitations** |
| * Increases access to TCM knowledge and care. * Standardises basic diagnostic steps. * Assists in telemedicine and remote consultation. * Supports training and continued learning | * May oversimplify complex or nuanced cases. * Lacks the full sensory input of a human practitioner (e.g. pulse or smell) * Cannot replace the experience, empathy, and intuition of trained TCM professionals |

TCM bots represent a fusion of ancient medical wisdom and cutting-edge AI. They act as digital assistants, educators, and advisors—helping modernise TCM while preserving its core diagnostic philosophy.

**Chatbots**

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| --- | --- |
| Chatbot | Description |
| **HuatuoGPT** | Collaboratively developed by Chinese institutions, it simulates clinical consultations and diagnostic reasoning using TCM principles. It features syndrome differentiation, herbal and acupuncture recommendations, and patient education. |
| **TCM-GPT** | Trained on classical texts and TCM clinical guidelines, it interprets symptoms and provides syndrome analysis and treatment suggestions. It is commonly used in medical education, diagnostic support, and case simulation. |
| **QiBo** | It is designed for TCM theoretical frameworks and focuses on syndrome classification and diagnostic simulation. |
| **TCM Virtual Consultation Mini-Programs (WeChat Bots)** | Self-assessment tools guide users through a consultation-style interaction that features constitution typing, dietary advice, and herbal suggestions. |
| **Acupuncture Master (Custom GPT)** | Built on ChatGPT with added acupuncture and TCM datasets, it offers point selection, diagnosis guidance, and treatment planning. |
| **Ming-MOE** | Developed by the Chinese academic and AI research community, it is a multimodal AI model that integrates TCM clinical, visual, and text data for intelligent assistance. |
| **Zhongjing-LLaMa** | Scholarly TCM bot trained to interpret classical Chinese medical literature that supports academic research and historical text interpretation. |
| **TCM Diagnostic Expert Systems (Legacy Bots)** | Rule-based expert systems that mimicked TCM diagnostic logic. Early prototypes were used in hospitals and universities for clinical simulation. |
| **CPMI-ChatGLM / MdChatZH** | Developed by Chinese medical informatics groups, they are specialised TCM chatbots used for data-driven diagnosis and herbal compatibility checks. |
| **ChatTCM (Experimental)** | Provides conversational support for patient questions, constitution typing, and herbal suggestions. |
| **JingFang** | A TCM-specific large language model (LLM) designed for expert-level medical diagnosis and syndrome differentiation-based treatment. Supports practitioners in delivering precise diagnoses and personalised treatment plans. |
| **BianCang** | A TCM-focused LLM was developed to address challenges in TCM diagnosis and syndrome differentiation that enhance diagnostic and differentiation capabilities, offering valuable insights for future research. |
| **HBot** | A healthcare chatbot for TCM applications, integrating 3D human body visualisation. It assists users in understanding TCM concepts and therapies through interactive visualisations. |
| **TCM Assistant (YesChat)** | An AI-powered TCM consultation tool designed for experienced practitioners that supports practitioners in refining their practice with detailed diagnostic and treatment support |
| **TCM Study Buddy (YesChat)** | A specialised chatbot designed to support TCM students and practitioners in learning that enhances the learning experience by facilitating the understanding of complex TCM concepts. |
| **Wang She Wen Shan** | An AI-powered mini-program for tongue diagnosis and dietary guidance that Streamlines TCM consultations by integrating traditional tongue diagnosis with AI image recognition technology |
| **GuangYi QiZhi** | A large-scale TCM model integrated into hospital workflows that enhances clinical practice by providing AI-assisted support throughout the hospital's workflow. |

## Chapter 24: Robotic Acupuncture

Robotic acupuncture is an emerging frontier in integrating artificial intelligence (AI), robotics, and Traditional Chinese Medicine (TCM). It seeks to enhance the delivery of acupuncture by leveraging advanced technologies to achieve greater precision, consistency, and potential accessibility, particularly in remote or clinical settings where traditional hands-on treatment is not feasible.

Robotic-assisted acupuncture involves using intelligent systems to identify, insert, and stimulate acupuncture points on the human body, autonomously or under a trained practitioner's supervision. These systems are designed not to replace human acupuncturists but to serve as clinical assistants or extend care capabilities, particularly in scenarios requiring high accuracy or telemedicine solutions. Key Features of Robotic-Assisted Acupuncture include:

* **3D Anatomical Mapping and Point Localisation**: Advanced imaging technologies, such as 3D body scanning and anatomical landmark detection, allow robotic systems to precisely locate acupuncture points based on the patient’s unique morphology. AI algorithms customise point identification beyond static textbook positions, enabling tailored treatment for each individual.
* **Robotic Needle Insertion and Manipulation**: Precision robotic arms are engineered to control needle insertion with exact depth, angle, and force. Some systems can even simulate traditional manual techniques, such as lifting, thrusting, or twirling, ensuring therapeutic accuracy and consistency.
* **Sensor Feedback and Real-Time Adjustment**: Built-in pressure, resistance, and biofeedback sensors (e.g., EMG, GSR) monitor the patient’s response during needling. These allow the system to adjust stimulation dynamically, optimising comfort and effectiveness while maintaining safety.
* **Non-Invasive Alternatives**: In jurisdictions with regulatory or ethical concerns regarding automated needling, robotic platforms are being developed for **laser** acupuncture or electroacupuncture, offering non-invasive solutions with automated precision in point stimulation.
* **Teleoperated and Remote-Control Capabilities**: With growing demand for accessible healthcare, robotic acupuncture systems offer the potential for remote treatment. Licensed practitioners can supervise or operate robotic devices from a distance, delivering care to underserved or geographically isolated populations.

China has led efforts in developing robot-assisted acupuncture systems for treating musculoskeletal and neurological conditions, often in research hospitals and university settings. Japan and Korea have piloted robotic arms for guided needling using electromyography (EMG) feedback to increase accuracy. The United States and Europe have focused primarily on robotic laser acupuncture and electrostimulation platforms, prioritising non-invasive applications for safety and accessibility. Future applications may include fully autonomous systems in space medicine, eldercare facilities, or even robotic clinics where AI-based diagnostic tools (e.g., facial recognition, pulse analysis, tongue scanning) are integrated into one unified treatment platform.

Robotic acupuncture illustrates a transformative path forward where TCM can engage with high-precision technology to maintain its therapeutic depth while expanding its reach and adaptability. As these technologies evolve, they promise to uphold the art of acupuncture within the framework of modern healthcare innovation.

**Notable Robotic-Assisted Acupuncture Prototypes**

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| --- | --- | --- |
| Prototype | Develop | Description |
| **OptiTrack-Based Acupuncture Robot** | **China, 2025** | Utilises the OptiTrack motion capture system for precise acupoint localisation, a collaborative robotic arm for needle insertion, and a De Qi sensation detection system. Achieved a positioning error within 3.3 mm, aligning closely with professional acupuncturists' standards. Needle insertion trajectory maintained a mean deviation distance of 0.02 mm and a deviation angle of less than 0.15°. The De Qi detection system demonstrated an average accuracy of 95.19%, effectively identifying sensations like "Tong," "Suan," "Zhang," and "Ma. Designed to streamline the acupuncture process, increase efficiency, and reduce practitioner fatigue, with potential applications in treating conditions like low back pain. |
| **MRUCT: Mixed Reality Acupuncture Guidance System** | **China–USA, 2025** | Combines ultrasonic computed tomography (UCT) with mixed reality (MR) to visualise acupuncture points in real-time. Provides a 3D anatomical reconstruction of the patient's arm, allowing for accurate needle insertion guided by MR overlays. Employs an attention-adaptive 3D user interface (3DUI) to assist practitioners during needle placement. Aims to enhance training for new practitioners and medical students by providing visual aids and real-time guidance, potentially reducing the learning curve associated with mastering acupuncture techniques. |
| **RT-DEMT: Real-Time Acupoint Detection Model** | **China, 2025** | A hybrid model combining the Mamba state-space model and Transformer architecture to achieve efficient global information integration for acupoint localisation tasks. Achieved an average Euclidean distance pixel error (EPE) of 7.792 on a private dataset of acupoints on the human back. Demonstrated an average time consumption of 10.05 milliseconds per localisation task, improving accuracy and speed by approximately 14% compared to previous models. Enhances the efficacy of acupuncture treatment and demonstrates the commercial potential of automated acupuncture robot systems. |
| **Analysis and Design of an Acupuncture Robot System** | **China, 2024** | Develop an acupuncture robot capable of replacing manual treatments for specific points. Utilises machine vision for spatial registration of the robotic arm, patient, acupuncture tools, and optical navigator to locate acupuncture points accurately. Implements a needle insertion mechanism guided by a trajectory algorithm that ensures precise needle placement while avoiding obstacles. Aims to standardise acupuncture treatments and improve the reproducibility of needle insertion techniques. |

## Chapter 25: AI-Powered Tuina Massage Robots

Tuina massage is a traditional hands-on therapeutic technique rooted in Traditional Chinese Medicine (TCM) principles. It is primarily used to promote the flow of qi and blood through the meridians, restore physiological balance, and support immune function. Tuina serves preventive and curative functions, treating various musculoskeletal and internal disorders by manipulating the body's soft tissues and energy pathways.

Integrating Artificial Intelligence (AI) into tuina massage therapy represents a frontier in modernising this ancient practice. Although still in its developmental stages, AI-powered massage robotics is emerging as a promising tool for enhancing clinical efficacy, increasing accessibility, and improving treatment standardisation. These intelligent systems aim to replicate core tuina techniques such as acupressure, vibration, and percussion. However, current technologies face challenges in fully reproducing the complexity and nuance of manual methods such as gentle stroking, dynamic stretching, and intricate kneading.

Two primary categories of robotic tuina technology are under development: vibration-based and percussion-based massage systems. These devices utilise AI algorithms and sensor technologies to simulate acupressure and deliver consistent pressure to specific points, providing a semi-automated version of tuina therapy. While they cannot yet replicate the dexterity and intuition of a human practitioner, they offer repeatable, data-driven treatments. They can be especially useful in rehabilitation, home care, and wellness settings.

EMMA (Expert Manipulative Massage Automation) is a notable innovation in this space, developed by AiTreat Pte Ltd in Singapore. EMMA is an AI-driven therapeutic massage robot designed to deliver precision tuina massage. It uses advanced sensor arrays, including pressure sensors and stiffness detectors, to locate areas of muscle tension and acupoint regions. EMMA can automatically adjust the intensity and angle of treatment in real time, based on the patient's feedback and biomechanical data. Key features of EMMA include:

* **Machine learning algorithms** that process muscle resistance patterns and physiological feedback to personalise massage protocols.
* **Internet of Things (IoT)** connectivity, enabling EMMA to store and analyse treatment data over time for ongoing refinement.
* **Acupoint recognition** models that allow EMMA to simulate TCM diagnosis by identifying therapeutic zones through sensor data, mimicking the pattern-recognition skills of an experienced practitioner.

These capabilities make EMMA more than a mechanical tool—it functions as an intelligent therapeutic assistant. It bridges the diagnostic and treatment processes, using AI to determine effective intervention zones and modulate technique dynamically. Through continued training and data collection, such AI systems can improve in precision and efficacy over time, potentially supporting the work of human practitioners and expanding access to therapeutic massage care.

As research and development in this area progress, AI-powered tuina robots will likely become increasingly sophisticated. Future advancements may include multi-modal systems integrating facial recognition, thermal imaging, and biometric feedback to create more personalised treatment experiences. Ultimately, AI-powered tuina massage represents a key example of how technology can extend the reach and capability of TCM, ensuring that its time-tested principles continue to benefit patients in the modern era.

# PART 6: Large Language Models

The rapid advancement of generative artificial intelligence, particularly large language models (LLMs), is ushering in a new era for Traditional Chinese Medicine (TCM). Originally developed for natural language processing (NLP) across various disciplines, LLMs are now being adapted and fine-tuned to meet TCM's specific linguistic, diagnostic, and conceptual needs. These models represent a major technological breakthrough in how traditional knowledge can be digitised, interpreted, and applied in clinical practice, research, and education.

LLMs, such as GPT-based models, are trained on massive textual datasets using self-supervised learning techniques. Through pre-training and fine-tuning, they learn to identify patterns, extract contextual meaning, and generate coherent, context-sensitive text in response to prompts. When tailored for TCM, these models can interpret ancient texts, assist in syndrome differentiation, develop personalised treatment suggestions, and support scholarly translation and teaching. Their inferential capabilities and semantic sensitivity offer exciting new tools for bridging ancient wisdom with modern computational power. Core Capabilities of LLMs in TCM include:

1. **Natural Language Processing (NLP) for Classical and Modern Texts**: LLMs can analyse and translate complex classical TCM literature, including texts in Classical Chinese, offering new pathways for historical interpretation, standardisation, and knowledge extraction.
2. **Clinical Decision Support and Diagnostic Assistance**: By processing clinical notes, patient records, and symptom descriptions, LLMs can assist practitioners in syndrome differentiation, suggest treatment strategies (herbal, acupuncture, dietary), and validate proposed diagnoses using knowledge from TCM databases.
3. **Educational Applications**: LLMs support the training of TCM students by simulating virtual case studies, generating diagnostic questions, and offering guided explanations of syndrome patterns and treatment principles.
4. **Research and Innovation**: These models can mine TCM data for drug discovery, herbal formula optimisation, and mechanism-of-action mapping by linking symptomology with biochemical pathways and classical TCM theory.
5. **Multilingual and Cross-Cultural Adaptation**: LLMs facilitate global dissemination of TCM by enabling multilingual translation, cultural adaptation, and international communication of medical concepts.

Numerous domain-specific LLMs have been developed in recent years to integrate deep knowledge of TCM with the flexibility of generative AI. Notable examples include:

* **ChatGPT** (OpenAI): Widely used and adaptable for general TCM tasks with fine-tuning.
* **TCM-GPT**: Trained specifically on TCM clinical guidelines and classical texts.
* **QiBo**: Named after the legendary physician, focuses on diagnostic simulation and syndrome classification.
* **HuatuoGPT**: Developed to simulate consultations, integrating modern and classical diagnostic frameworks.
* **IvyGPT** and **Zhongjing-LLaMa**: Designed for scholarly interpretation and classical knowledge translation.
* **MdChatZH**, **CPMI-ChatGLM**, **Ming-MOE**, **HuoTuo**, **Bianqu**, and **ChatGLM-6b/ChatGLM2-6b**: Developed by various institutions across China to support a broad spectrum of diagnostic, educational, and therapeutic TCM tasks.
* **Tsinghua University’s General Language Model (GLM)** and **Shanghai AI Lab's InternLM**: Advanced multilingual models with potential TCM standardisation and cross-disciplinary integration applications.

These models differ in their design, training data, and clinical focus, but all contribute to modernising TCM and increasing its accessibility, consistency, and evidence base. The integration of LLMs into TCM represents a **paradigm shift**. These models enable:

* **Standardised knowledge representation**, reducing practitioner variability.
* **Improved diagnostic accuracy** through advanced pattern recognition
* **Deeper personalisation of treatment**, aligning with TCM’s holistic values.
* **Faster innovation** in herbal drug development and syndrome research
* **Scalable education and consultation platforms**, especially in underserved or rural areas

Finishing LLMs with high-quality, annotated TCM corpora and developing robust prompt engineering frameworks will ensure their reliability, safety, and cultural sensitivity. When paired with ethical frameworks and practitioner oversight, LLMs will preserve the depth of TCM’s philosophical tradition and amplify its relevance in a digital, data-driven world.

### Classifying Prescriptions

Large Language Models (LLMs) can classify Traditional Chinese Medicine (TCM) prescriptions into predefined efficacy categories, offering a structured and systematic approach to understanding herbal formulations. By encapsulating complex prescription data—including the prescription name, constituent herbs, dosage, therapeutic actions, and clinical indications—LLMs provide a more precise and efficient tool for analysing and categorising prescriptions. This capability not only aids in the organisation of TCM knowledge but also supports clinical decision-making, prescription retrieval, and treatment optimisation. Moreover, it facilitates the standardisation of prescription terminology across regions and institutions, enabling better integration with digital health systems, AI diagnostic tools, and modern pharmacological research.

Large Language Models (LLMs) have significantly advanced the classification of Traditional Chinese Medicine (TCM) prescriptions by systematically categorising them into predefined efficacy groups. These models encapsulate complex prescription information, including the prescription name, constituent herbs, therapeutic efficacy, and clinical indications, thereby providing a more precise and efficient prescription analysis and classification tool.

For instance, HuatuoGPT, developed by researchers at the Chinese University of Hong Kong, Shenzhen, and the Shenzhen Research Institute of Big Data, is a medical LLM fine-tuned with real-world clinical data and distilled data from models like ChatGPT. This dual-training approach enables HuatuoGPT to perform tasks such as syndrome differentiation and treatment recommendation, effectively aligning with the diagnostic thinking patterns of TCM practitioners. Its capabilities include accurately classifying prescriptions based on therapeutic efficacy, supporting clinical decision-making and standardising treatment protocols.

Similarly, TCM-GPT, a model introduced by researchers focusing on domain adaptation in TCM, employs efficient pre-training techniques on a large-scale TCM-specific corpus. By leveraging methods like Low-Rank Adaptation (LoRA), TCM-GPT aligns closely with TCM-related tasks, including prescription classification and diagnosis. The model has demonstrated superior performance in categorising prescriptions according to their efficacy, thus enhancing the precision of treatment strategies and facilitating the integration of TCM knowledge into modern healthcare systems.

These advancements in LLM applications streamline the classification process of TCM prescriptions and contribute to the broader goals of standardising TCM practices and integrating them with contemporary medical frameworks.

**Large Language Models (LLMs)**

|  |  |  |  |
| --- | --- | --- | --- |
| Model | Developer | Primary Focus | Special Strengths |
| ChatGPT (OpenAI) | OpenAI | General-purpose LLM, adaptable for TCM with fine-tuning | Flexible, strong NLP performance |
| TCM-GPT | Unknown (Domain-specific) | Trained on TCM guidelines and classical texts | High performance in TCM-specific tasks due to tailored pretraining |
| QiBo | China-based Institutions | Diagnostic simulation and syndrome classification | Nuanced handling of TCM theory |
| HuatuoGPT | Various (China) | Simulates TCM consultations, integrates classical & modern diagnostics | Interactive consultation simulation |
| IvyGPT | Academic Institutions | Classical TCM interpretation and scholarly translation | Classical knowledge interpretation |
| Zhongjing-LLaMa | Academic Institutions | Translation of classical TCM literature | Deep classical literature understanding |
| MdChatZH | Various (China) | TCM diagnostics, education, therapy | Robust clinical application |
| CPMI-ChatGLM | CPMI | Diagnostic and therapeutic applications | Guided clinical support |
| Ming-MOE | Chinese Research Labs | Broad-spectrum TCM support | Comprehensive diagnostic abilities |
| HuoTuo | Chinese Research Labs | Broad-spectrum TCM support | Covers a wide therapeutic range |
| Bianqu | Chinese Research Labs | Broad-spectrum TCM support | Historical insights |
| ChatGLM-6b / ChatGLM2-6b | Chinese Research Labs | General diagnostic and educational tools | Advanced educational capabilities |
| Tsinghua GLM | Tsinghua University | Multilingual, standardisation and integration | Cross-lingual support for TCM |
| InternLM | Shanghai AI Lab | Multilingual integration, cross-disciplinary applications | Interdisciplinary medical applications |

## Chapter 26: Chat GPT and Acupuncture Master

ChatGPT is a generative AI chatbot capable of producing human-like responses across various topics. It was developed by OpenAI and launched in 2022. It allows users to tailor conversations based on preferred style, depth, format, and language. Custom GPTs are built on ChatGPT’s foundation, enriched with domain-specific data to suit specialised applications, such as *Acupuncture Master*, a model focused on Traditional Chinese Medicine (TCM) and acupuncture.

Acupuncture Master is trained on an extensive dataset comprising classical Chinese medical texts (e.g., *Huangdi Neijing*, *Nan Jing*, *Shang Han Lun*, *Jin Gui Yao Lue*), contemporary TCM interpretations, peer-reviewed journal research, and standardised frameworks including the Eight Principles, Five Elements, meridian theory, qi-blood-body fluid dynamics, and modern acupuncture nomenclature. Its purpose is to synthesise this knowledge into clinically relevant responses, supporting TCM practitioners with case-taking, syndrome differentiation, treatment planning, and acupuncture point selection.

While ChatGPT has demonstrated sufficient accuracy for clinical advisory purposes, especially during inquiry and initial diagnostic stages, its limitations remain clear. It cannot perform the observational and tactile aspects of TCM, such as pulse taking, tongue diagnosis, olfactory cues, point location, or needling technique. Furthermore, it lacks human qualities such as empathy, communication finesse, and the practitioner-patient rapport essential to clinical practice. Covelo (2025) noted that AI may support and even exceed practitioner performance in knowledge synthesis and decision-support tasks. Still, it cannot yet replicate the nuanced, embodied skill set acquired through extensive clinical experience.

# PART 7: Discussion

This book section explores critical themes at the intersection of Artificial Intelligence (AI) and Traditional Chinese Medicine (TCM) that extend beyond the core diagnostic and treatment technologies discussed elsewhere. These themes highlight how AI is reshaping the foundational aspects of TCM practice and philosophy, offering enhancement and evolution. The discussion includes:

* **TCM Prescription:** How AI enhances prescription formulation through data-driven insights and intelligent recommendation systems.
* **Clinical Efficacy:** AI’s role in improving treatment accuracy, safety, and outcomes across herbal medicine and acupuncture.
* **Objective Measurement:** Transforming traditionally subjective diagnostic methods into quantifiable, reproducible metrics.
* **Personalised Medicine:** Leveraging AI to tailor treatments based on individual profiles, including constitution, symptoms, and lifestyle.
* **AI-Assisted Decision Making:** The use of AI to support clinical reasoning and syndrome differentiation without replacing practitioner expertise.
* **The Modernisation of TCM:** How AI contributes to the digital transformation, standardisation, and global integration of TCM.

Together, these topics illustrate the multifaceted ways AI is supporting and advancing the philosophical and clinical foundations of TCM in the 21st century.

## Chapter 27: TCM Prescription

Prescription recommendation is a critical area where artificial intelligence (AI) significantly advances the practice of Traditional Chinese Medicine (TCM). Leveraging models such as Generative Adversarial Networks (GANs), deep cross neural networks, and other deep learning architectures, AI systems can now generate highly customised herbal prescriptions based on complex, multi-dimensional patient data.

These AI models integrate various variables, from historical treatment data and symptom patterns to patient-specific chemical, physiological, and pharmacological profiles. By doing so, they can recommend formulas that are not only consistent with the classical principles of syndrome differentiation but also aligned with the biochemical realities of the patient's condition. This enhances the precision, safety, and efficacy of the prescribed treatment.

AI systems improve on traditional trial-and-error approaches by learning from vast clinical data repositories, including successful and unsuccessful treatment outcomes. They analyse patterns in herb compatibility, dosage variations, individual constitution types, and drug-herb interactions. For example, deep learning models can detect how certain herbs have historically performed in treating syndromes similar to the patient's, adjusting formula ratios accordingly for optimal therapeutic impact. Moreover, these intelligent systems can incorporate up-to-date pharmacological findings, including each herb's bioavailability, metabolic pathways, and toxicity thresholds of individual compounds. This is especially important for patients undergoing complex treatments or those using both TCM and Western medications, where the risk of adverse interactions is higher.

Through real-time optimisation, AI allows practitioners to iteratively refine prescriptions based on patient feedback, symptom progression, and treatment efficacy. Some systems even integrate with wearable health monitors, updating prescriptions dynamically in response to changes in physiological indicators such as heart rate variability, body temperature, or sleep quality.

Combining classical TCM knowledge with cutting-edge computational intelligence, AI-enabled prescription systems support a new era of evidence-based, patient-centred herbal medicine. These innovations preserve TCM's philosophical and diagnostic richness while improving consistency, safety, and clinical outcomes.

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## Chapter 28: Clinical Efficacy

AI ensures clinical efficacy in Traditional Chinese Medicine (TCM)—including herbology and acupuncture—by enhancing precision, personalisation, and evidence-based decision-making. It supports traditional practices and modern research through data analysis, pattern recognition, and predictive modelling.

### Herbology

AI significantly enhances the clinical efficacy of herbology in Traditional Chinese Medicine (TCM) by introducing data-driven precision, safety, and standardisation to traditionally experience-based practices. These AI-driven capabilities make herbology more precise, safe, and scientifically grounded, ensuring its continued relevance in modern, integrated healthcare.

One of AI's key contributions is formulation optimisation by analysing vast datasets—including classical texts, pharmacological research, and real-world clinical case reports—AI systems can assess herb compatibility, dosage ratios, and compound interactions. This allows for formula adjustments tailored to an individual’s profile, improving the precision of treatments while reducing the risk of adverse effects. Such optimisation bridges the gap between traditional empirical knowledge and personalised medicine.

AI also excels in herb-compound-disease mapping. Through technologies like network pharmacology and knowledge graphs, AI can link herbs to their active chemical constituents, biological targets, and associated disease pathways. This clarifies how herbal formulas exert their therapeutic effects and guides the development of more targeted and effective treatments.

In addition, AI supports the creation of personalised prescriptions by analysing a patient’s symptoms, constitution, medical history, and laboratory results. These personalised strategies ensure that treatment is aligned with each patient's unique condition, which enhances efficacy and supports better clinical outcomes—a key principle in TCM.

Furthermore, AI plays a vital role in toxicity and interaction detection. AI can identify potential contraindications or harmful herb-drug interactions by cross-referencing herbal components with drug databases and clinical reports. This is particularly important when TCM is practised alongside Western medicine, where complex treatment regimens can pose safety risks.

Lastly, AI contributes to standardisation and quality control. AI ensures that herbal ingredients meet consistency and potency standards through tools like chemical fingerprinting and blockchain-enabled supply chain traceability. This is essential for clinical reliability and broader regulatory acceptance of TCM in global healthcare systems.

### Acupuncture

AI significantly enhances the clinical efficacy of acupuncture by refining diagnostic accuracy, personalising treatments, and supporting consistent therapeutic delivery. Together, these advancements show how AI is not replacing acupuncture’s core principles but enhancing them, combining the wisdom of tradition with the precision of technology to improve patient outcomes.

A major contribution of AI is in acupoint selection and optimisation. By analysing large-scale clinical datasets, AI can determine the most effective combinations of acupoints for treating specific diseases and syndromes. These data-driven insights support dynamic treatment planning, adjusting point prescriptions in real time based on evolving symptoms or therapeutic responses. This flexibility aligns closely with acupuncture’s adaptive nature and improves overall effectiveness.

Regarding treatment personalisation, AI integrates individual patient data, such as pain location, constitution, pulse type, and symptom profiles, to tailor point selection, needling depth, stimulation techniques (manual, electrical, or laser), and session frequency. This level of precision fosters a more targeted and responsive treatment, increasing the likelihood of rapid and sustained patient improvement.

AI also plays a key role in efficacy evaluation. By using standardised metrics, patient-reported outcomes, and biometric feedback (e.g. heart rate variability, skin conductance), AI systems can assess the effectiveness of each session and modify protocols accordingly. This creates a learning feedback loop where AI continuously refines treatment decisions over time, supporting evidence-based acupuncture practice.

Finally, AI-powered robotic and image-guided assistance contributes to clinical consistency and precision. In training and research settings, AI-driven robotic systems can perform needling with exceptional accuracy, ensuring repeatability and reducing practitioner variability. These tools are especially valuable in standardising protocols for clinical trials or education, helping to build stronger scientific support for acupuncture’s efficacy.

### Cross-Disciplinary Clinical Support

AI enhances clinical efficacy in Traditional Chinese Medicine (TCM) through cross-disciplinary clinical support, integrating data science, diagnostics, education, and research to improve decision-making and treatment outcomes. AI’s cross-disciplinary applications strengthen the clinical foundations of TCM, promote consistency, and bridge the gap between traditional wisdom and contemporary evidence-based medicine.

One of the key applications is through Clinical Decision Support Systems (CDSS). These AI-driven platforms integrate diagnostic inputs, such as tongue images, pulse data, facial analysis, symptom inquiry, and laboratory results, to provide comprehensive syndrome differentiation and suggest treatment strategies. By synthesising information from multiple sources, CDSS helps practitioners make faster, more accurate, and evidence-informed decisions, improving safety and efficacy in patient care.

AI also plays a critical role in outcome prediction. AI can identify patterns that predict individual treatment responses by analysing large datasets of historical patient records and their treatment outcomes. This allows for early identification of high-risk patients and enables practitioners to proactively adjust therapies, improving patient prognosis and reducing the likelihood of ineffective treatments.

In data-driven research, AI accelerates the validation of TCM therapies by mining clinical trials, case reports, and published studies. This process uncovers evidence supporting specific interventions and contributes to the creation of standardised clinical guidelines. Such research is essential for gaining broader regulatory acceptance and integrating TCM more firmly into global healthcare systems.

Finally, AI significantly enhances education and training in TCM. Students and practitioners can engage in interactive learning that mimics real-world diagnostic and treatment scenarios through intelligent simulations and virtual patient models. These tools improve diagnostic reasoning, treatment planning, and overall clinical competency, ensuring the next generation of TCM professionals are better equipped for modern practice. AI enhances clinical efficacy in TCM by:

|  |  |
| --- | --- |
| Domain | Description |
| **Diagnostics** | Multi-modal analysis (tongue, pulse, inquiry), syndrome differentiation |
| **Research** | Clinical validation, network pharmacology, efficacy prediction |
| **Education** | Diagnostic training, outcome simulation, and clinical decision-making tools |
| **Herbology** | Personalised prescriptions, herb-drug interaction detection, formula optimisation |
| **Acupuncture** | Tailored point selection, treatment outcome tracking, precision and consistency |

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By bridging traditional knowledge with modern technology, AI empowers Traditional Chinese Medicine (TCM) to become more predictable, personalised, and evidence-based, while preserving its foundational holistic philosophy. Through data-driven insights and intelligent analysis, AI enhances the accuracy and consistency of diagnosis and treatment, supports deeper understanding of syndrome patterns and herb-drug interactions, and enables tailored therapeutic strategies that honour the individual as a whole—mind, body, and spirit. This integration not only strengthens clinical efficacy but also ensures that the timeless principles of TCM remain relevant and impactful in modern healthcare.

## Chapter 29: Objective Measurement

AI facilitates objective measurement in Traditional Chinese Medicine (TCM) by transforming its traditionally subjective and experience-based diagnostic methods into quantifiable, reproducible, and analysable data. Through these innovations, AI provides a more standardised and evidence-based foundation for TCM practice, improving diagnostic accuracy, supporting research validation, and enabling integration into global healthcare systems.

### Digitisation of the Four Diagnostic Methods

TCM relies on inspection, listening/smelling, inquiry, and palpation. AI technologies objectify these as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| Inspection | **Listening and Smelling** | Inquiry | Palpation |
| **Digital Tongue Diagnosis**: AI-powered image recognition evaluates colour, coating, moisture, shape, and fissures of the tongue. | **Voice and Breath Analysis**: To assess health, AI audio processing detects vocal quality, tone, and breathing patterns. | **Natural Language Processing (NLP)**: AI interprets patient symptom descriptions using NLP, standardising the data for further analysis. | **Electronic Pulse Waveform Sensors**: Tactile arrays and robotic fingers equipped with pressure sensors replicate the sensitivity of human fingertips. |
| **Facial Analysis**: Machine learning models assess complexion, asymmetry, and facial zones linked to organ systems. | **Odour Recognition:** Experimental AI systems use chemical sensors to classify body or breath odours, which are potentially linked to internal imbalances. | **LLMs (like TCM-GPT)** analyse case notes and history to suggest likely syndrome patterns or treatment options. | AI algorithms analyse pulse waveforms, rhythm, strength, and depth to classify pulses into TCM categories (e.g., wiry, slippery, thin). |

### Standardised Data Collection and Processing

AI systems use wearables and diagnostic devices to continuously collect consistent physiological data such as heart rate variability, skin temperature, and sleep patterns. These real-time data streams offer a dynamic view of a patient’s health status, which aligns well with the holistic monitoring principles of Traditional Chinese Medicine (TCM). Advanced AI algorithms filter, reduce noise, and extract features from raw data, eliminating artefacts and enhancing signal clarity. This preprocessing ensures that only accurate and meaningful information is used for analysis, improving diagnostic precision. By transforming inconsistent or subjective observations into standardised metrics, AI enhances physiological data's reliability, repeatability, and clinical value, supporting more informed decision-making in TCM diagnosis and personalised treatment planning.

### Machine Learning and Pattern Recognition

AI models such as BiLSTM, Convolutional Neural Networks (CNNs), and Transformers are trained on large-scale clinical datasets to identify complex symptom patterns, match patient profiles with TCM syndrome types, and predict likely outcomes based on historical case data.

These models can analyse multidimensional inputs—including tongue images, pulse waveforms, and symptom inquiries—to generate accurate and consistent diagnostic suggestions. By learning from a wide range of practitioner records and validated cases, AI reduces the influence of individual practitioner bias and subjectivity. This standardisation enhances the reproducibility of diagnosis and treatment across different settings, contributing to a more evidence-based and scalable application of TCM practices.

### Quantification and Visualisation Tools

AI facilitates the development of quantifiable diagnostic metrics, such as tongue shape index, coating distribution, pulse peak ratio, and waveform variability, which align with traditional TCM diagnostic categories. These metrics transform subjective observations into objective data points that can be analysed, compared, and tracked.

Visualisation tools like interactive dashboards enable practitioners and patients to monitor diagnostic indicators and treatment progress. This enhances diagnostic precision and improves patient engagement, providing transparent and comprehensible feedback that supports shared decision-making and long-term care planning.

### Building Diagnostic Standards

By analysing large-scale clinical datasets, AI helps establish statistically validated norms and thresholds for diagnostic indicators, such as standard ranges for tongue hue, pulse waveform characteristics, or facial colouration. This data-driven approach supports the creation of objective benchmarks that enhance diagnostic consistency. Furthermore, it promotes the international standardisation of TCM diagnostic practices, enabling reproducibility across practitioners, cultures, and healthcare systems. This harmonisation is essential for integrating TCM into global medical frameworks, fostering cross-border collaboration, research, and regulatory acceptance.

### Clinical Decision Support

AI supports practitioners by offering diagnostic suggestions derived from large-scale data analysis, effectively functioning as a statistically grounded second opinion. By leveraging advanced pattern recognition and historical case comparisons, AI can identify correlations between symptoms, syndromes, and treatment outcomes. This enhances diagnostic accuracy and provides reassurance, particularly for less experienced practitioners. Integrating AI into the diagnostic workflow makes clinical decision-making more consistent and evidence-informed, reinforcing practitioner confidence while upholding the holistic integrity of Traditional Chinese Medicine.

AI facilitates objective measurement in TCM by replacing subjective visual and tactile judgments with digital sensors and imaging, translating qualitative descriptions into quantitative data, using AI models to identify, classify, and predict TCM syndromes and supporting standardisation and reproducibility, essential for scientific validation and global integration. Ultimately, AI transforms traditional diagnostic wisdom into a data-driven, evidence-based system, ensuring the longevity and credibility of TCM in modern medicine.

## Chapter 30: Personalised Medicine

Personalised medicine represents a transformative shift in healthcare—from a one-size-fits-all model to a tailored approach considering an individual’s genetic makeup, lifestyle, environment, and health history. Li et al. (2024) explain that personalised medicine involves developing clinical decisions that best meet each patient's needs. In this respect, Traditional Chinese Medicine (TCM) has long embraced individualised care, tailoring treatments based on constitution, syndrome differentiation, and nuanced observations gathered through the four diagnostic methods.

Artificial Intelligence (AI) is poised to enhance this personalised approach significantly in the modern era. By leveraging machine learning, data mining, and deep learning algorithms, AI systems can analyse vast amounts of complex data—including symptom patterns, pulse and tongue images, medical histories, and even chemical signatures—refining and customising diagnosis and treatment strategies in unimaginable ways.

AI offers powerful tools for processing and interpreting the multifaceted data central to TCM practice. Its key contributions include:

* **Pattern Recognition**: AI models can identify and correlate complex symptom patterns with TCM syndromes. This facilitates more precise syndrome differentiation and optimises the selection of herb formulas and acupoint prescriptions.
* **Chemical Data Integration**: Through the integration of network pharmacology, AI can analyse the chemical composition of herbal medicines concerning patient-specific biomarkers, allowing for safer, more targeted interventions. This is particularly valuable for treating chronic illnesses, where subtle variations in a patient's constitution can significantly affect treatment efficacy.
* **Health Data Mining**: AI algorithms can sift through massive datasets—clinical records, wearable health metrics, genetic profiles, and more—to uncover patterns and correlations. These insights support personalised treatment strategies aligned with each patient’s health profile, medical history, and lifestyle.
* **Predictive Modelling**: By analysing long-term health data, AI can anticipate disease progression and recommend preventive interventions, supporting a proactive model of care. It can also forecast patient responses to specific treatments and suggest real-time adjustments.

AI brings precision to TCM diagnosis by reducing human error and offering a consistent interpretation of data. Personalised prescriptions tailored to an individual’s constitution and symptomatology increase the likelihood of therapeutic success. AI can help detect potential herb-drug interactions or contraindications based on patient-specific chemical sensitivities. Tailored treatment fosters greater trust and compliance, as patients feel their unique needs are being understood and addressed.

AI’s integration with TCM is improving current diagnostic and therapeutic models and setting the stage for more advanced, data-driven approaches to health. AI in network pharmacology, multi-omics analysis, real-time monitoring through wearable technology, and large-scale patient databases for syndrome differentiation will deepen the personalisation of TCM treatment even further.

Ultimately, the convergence of AI and TCM represents the future of precision integrative medicine—blending ancient wisdom with cutting-edge technology to deliver patient-centred, highly individualised care. As TCM continues to evolve in the digital age, AI will remain an indispensable tool in realising its full potential.

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## Chapter 31: AI-Assisted Decision-Making

Artificial Intelligence (AI) is rapidly transforming the diagnostic and therapeutic landscape of Traditional Chinese Medicine (TCM), offering powerful tools for data analysis, syndrome differentiation, and treatment recommendation. However, despite these advancements, it is essential to emphasise that AI functions as a supportive adjunct, not a replacement, for the TCM practitioner.

While AI systems can process vast datasets, identify hidden patterns, and suggest clinical pathways with impressive speed and consistency, they lack the contextual judgment, clinical intuition, and holistic sensitivity experienced practitioners bring to the healing process. TCM is rooted in a rich tradition of observation, inquiry, and energetic interpretation that reflects physical symptoms and the patient's constitution, emotional state, environment, and lifestyle—all elements that require human discernment and empathetic engagement.

Li et al. (2024) affirm this point, stating:

*“It is paramount to underscore the intrinsic worth of human expertise, for the practitioner’s role in diagnosis and therapeutics remains irreplaceable. While AI shows vast potential in TCM, it cannot entirely substitute clinician expertise.”*

Practitioners provide more than technical diagnoses—they offer rapport, ethical reasoning, emotional support, and adaptive thinking, all crucial to TCM’s patient-centred model. AI, while capable of improving efficiency and standardisation, is ultimately dependent on human guidance for:

* Interpreting subtle diagnostic cues in complex or ambiguous cases
* Tailoring treatment to a patient’s changing physical and emotional states.
* Making ethical and compassionate decisions based on lived experience.
* Integrating cultural, spiritual, and personal factors into treatment planning

The optimal future lies not in replacing practitioners but in cultivating collaborative intelligence—a synergy between human insight and machine precision. In this model, AI systems support decision-making by providing evidence-informed insights, tracking treatment outcomes, and identifying patterns across populations. At the same time, practitioners maintain leadership in clinical judgment, therapeutic relationships, and integrating body-mind-spirit healing. By embracing AI as a co-pilot rather than a substitute, TCM can evolve without losing its essence, enhancing accessibility, safety, and individualised care while reaffirming the irreplaceable value of the human healer.

## Chapter 32: Digital TCM: Towards an Intelligent Future

The digitisation of Traditional Chinese Medicine (TCM) marks a pivotal evolution in preserving, disseminating, and advancing this ancient medical system. Digitisation involves converting classical texts, clinical case records, herb formularies, diagnostic criteria, and therapeutic techniques into digital formats that can be archived, analysed, and integrated with modern computational tools. This process enables the transformation of TCM from an empirical, paper-based tradition into a structured, data-rich knowledge system that can interface with contemporary technologies such as artificial intelligence, big data analytics, and cloud computing. Digitisation supports multiple goals:

* **Preservation of heritage**: Ancient TCM texts, many of which exist only in fragile or incomplete manuscripts, are digitised and archived to protect them for future generations.
* **Clinical integration**: By creating digital records of syndrome differentiation, herbal prescriptions, and acupuncture treatments, TCM can align more closely with modern health information systems.
* **Education and dissemination**: Digital platforms enable students and practitioners worldwide to access authentic TCM knowledge through e-learning, simulation, and mobile apps.
* **Scientific validation**: Structured digital data allows researchers to apply AI, statistical models, and evidence-based methods to study TCM efficacy and mechanisms.

### Digital TCM Strategy

China has been a global leader in advancing the Digital TCM Strategy, promoting the modernisation and global integration of Traditional Chinese Medicine through national-level planning and technology adoption. In 2021, the National Administration of Traditional Chinese Medicine (NATCM) initiated a strategic roadmap to digitise TCM resources, enhance interoperability with biomedical systems, and support AI-based research. Key goals of China’s digital TCM strategy include:

* **Establishing a unified digital infrastructure**: This includes building national databases for medicinal herbs, clinical case studies, diagnostic standards, and historical texts.
* **Developing intelligent diagnosis and treatment systems**: Using AI to support syndrome differentiation, herbal prescription suggestions, and acupuncture point selection.
* **Promoting TCM telemedicine**: Digital tools provide remote diagnosis and care, particularly in rural or underserved areas, increasing access to TCM services.
* **Integrating with Western medicine**: The digital framework supports cross-disciplinary data sharing and fusion, aligning TCM with global standards in evidence-based medicine.
* **Encouraging innovation and entrepreneurship**: Start-ups, research institutes, and universities are supported in developing smart TCM applications, robotic therapy tools, and wearable diagnostic devices.

The Digital TCM Strategy is part of a broader vision to establish "Smart TCM" systems, where data flows freely between hospitals, pharmacies, researchers, and regulatory bodies to create a cohesive digital TCM ecosystem.

### Digital Chinese Medicine Research

Digital Chinese Medicine Research refers to a new paradigm of scientific investigation in which TCM knowledge is digitised, modelled, and analysed using computational tools. It combines traditional theoretical frameworks with modern technologies such as:

* **Big data analytics** to identify hidden patterns in historical case studies or herbal interactions.
* **Knowledge graphs** to map relationships between diseases, herbs, symptoms, and diagnostic factors.
* **Natural language processing (NLP)** to extract structured data from classical texts.
* **Systems pharmacology and bioinformatics** to explore the molecular mechanisms of herbal medicines.
* **Digital twins and simulations** to model patient responses to TCM treatments in silico.

This form of research enables deeper insights into the complexity of TCM practices and facilitates integration with biomedical knowledge. For instance, researchers can use AI to simulate and optimise herbal formulations or identify gene targets corresponding to TCM syndromes. These digital tools help translate centuries of experiential wisdom into reproducible and testable frameworks, creating new opportunities for drug discovery, personalised medicine, and global collaboration.

Digital TCM represents a convergence of ancient healing and modern innovation. TCM is being preserved, standardised, and transformed through digitisation, structured data systems, and intelligent technologies. China’s strategic initiatives and global interest in integrative medicine have made Digital TCM a technical transformation and a cultural and scientific renaissance. As the field continues to evolve, digital TCM will serve as both a guardian of traditional wisdom and a guide to future healthcare innovation.

## Chapter 33: The Modernisation of TCM

As we enter the Fourth Industrial Revolution, humanity faces unprecedented opportunities alongside complex global challenges. Each previous industrial era marked a transformative shift in human society:

* **The First Industrial Revolution** transitioned agrarian societies into mechanised economies through steam power and early industrialisation.
* **The Second Industrial Revolution** heralded the Electrical Age, revolutionising production, communication, and infrastructure.
* **The Third Industrial Revolution** introduced information technology, transforming the global economy and reshaping human interaction.

Digital and physical systems are becoming deeply integrated in the Fourth Industrial Revolution. Technologies such as artificial intelligence (AI), big data, cloud computing, the Internet of Things (IoT), and 5G networks are converging, reshaping how we live, work, and relate to each other. These technological advancements also offer transformative possibilities for Traditional Chinese Medicine (TCM), enabling the field to evolve while remaining grounded in its classical roots.

### The Digitisation of TCM

The modernisation of TCM is more than a superficial upgrade. It profoundly reimagines how ancient medical wisdom can interact with contemporary technologies. Wang (2025) explains that this transformation can be understood through five hierarchical levels of digital integration:

1. **Objectification**—The first step is accurately recording objective clinical data. By digitising patient records, symptoms, tongue images, and pulse signals, the subjective elements of diagnosis can be quantified and preserved for analysis.
2. **Standardisation** – Establishing unified diagnostic criteria, terminology, and processes lays the groundwork for consistency across practices, regions, and research protocols. This step is essential for interoperability and scientific validation.
3. **Informatisation** – TCM theories and clinical knowledge must be structured into machine-readable formats. This allows for integration with health information systems and enables the application of AI and advanced analytics.
4. **Transformation** – Core TCM principles such as syndrome differentiation, the five elements, and qi dynamics are translated into computational logic. This enables the development of intelligent systems that model the reasoning processes of experienced practitioners.
5. **Intelligentisation** – At the highest level, AI-driven platforms autonomously learn, adapt, and apply TCM diagnostic frameworks in clinical support, research, and education, enhancing the precision, accessibility, and personalisation of care.

### Modernisation Beyond Westernisation

Modernising TCM does not mean diluting its foundational concepts to fit Western biomedical paradigms. Rather, it requires a nuanced integration—honouring TCM's complexity while embracing scientific tools to strengthen its application in a modern healthcare environment. This transformation includes:

* **Integrated Education, Research, and Clinical Practice**: Cultivating a unified system where clinical training, theoretical education, and scientific inquiry reinforce one another.
* **Convergence of TCM, Western Medicine, and Modern Science**: Encouraging dialogue and mutual enrichment to develop clinically effective and scientifically grounded hybrid models of care.
* **Interregional and Interdisciplinary Collaboration**: Involving stakeholders across geographic regions, academic disciplines, and healthcare sectors to create innovative, collaborative solutions.
* **Standardisation of Diagnostic Methods**: Codifying TCM diagnostic techniques such as pulse, tongue, and facial analysis into reproducible, teachable, and research-friendly protocols.
* **Preventative and Holistic Care**: TCM emphasises its strength in constitution-based and lifestyle-oriented treatment approaches by developing a global move toward proactive, preventative medicine.
* **Advancement of Theory and Methodology**: Developing frameworks that combine TCM theory with systems biology, metabolomics, and AI better to understand the body’s internal ecology and disease patterns.

The modernisation of TCM is not simply a technical upgrade but a cultural and scientific evolution. It positions TCM not as an alternative, but as a complementary and integrative pillar in global healthcare systems. By leveraging the tools of the Fourth Industrial Revolution, TCM can reaffirm its relevance, extend its international reach, and contribute meaningfully to the health challenges of the 21st century. Through thoughtful integration, we can preserve the soul of TCM while expanding its scientific foundation, ensuring its vitality for generations to come.

### AI’s Role in the Modernisation of TCM

Artificial Intelligence (AI) plays a central and transformative role in modernising Traditional Chinese Medicine (TCM), bridging ancient wisdom with cutting-edge technology. Rather than replacing TCM, AI is a powerful catalyst for revitalisation, ensuring its continued relevance in a data-driven, patient-centred, and globally integrated healthcare environment.

**Objectivity of Diagnostics**

Traditional Chinese Medicine (TCM) has historically relied on subjective diagnostic techniques—including tongue diagnosis, pulse reading, and symptom inquiry—that depend heavily on the practitioner's intuition, experience, and interpretive skill. While these methods are central to TCM's holistic nature, their variability can present challenges regarding consistency, training, and international acceptance.

Artificial Intelligence (AI) transforms these qualitative assessments into objective, quantifiable, reproducible data. Image recognition technologies, for example, can analyse features of the tongue, face, and skin with high precision, identifying colour, shape, texture, and coating characteristics that correlate with internal health conditions. Wearable sensors and diagnostic devices capture standardised pulse data, skin temperature, heart rate variability, and other physiological signals, translating subtle biofeedback into measurable parameters. Additionally, machine learning models trained on extensive clinical datasets can support syndrome differentiation by recognising patterns in patient symptoms, lab results, and biometric data. These AI-driven methods enable a more standardised and evidence-based approach to TCM diagnostics, improving accuracy and reliability across practitioners and institutions.

By objectifying traditional diagnostic practices, AI enhances diagnostic precision and lays the groundwork for international standardisation. This facilitates the broader integration of TCM into global health systems while preserving its foundational philosophies.

**Research and Knowledge Discovery**

AI excels at extracting meaningful insights from the vast and diverse body of Traditional Chinese Medicine (TCM) knowledge, encompassing unstructured and structured data sources. This includes classical texts, case reports, clinical trials, modern biomedical research, and digital repositories. AI can interpret and translate ancient Chinese medical literature by applying advanced technologies such as Natural Language Processing (NLP), making centuries of experiential wisdom accessible and usable in contemporary contexts. Furthermore, network pharmacology and knowledge graph construction allow AI to map intricate relationships between herbs, active compounds, biological targets, and diseases, shedding light on the multi-component, multi-target nature of TCM. Deep learning and graph neural networks (GNNs) are employed to uncover latent patterns and correlations within these relationships, enhancing the understanding of how herbal formulas exert their effects across various physiological systems.

Through these tools, AI accelerates drug discovery, validates traditional diagnostic and therapeutic theories, and uncovers novel mechanisms of action, thereby promoting a more scientific, evidence-based foundation for TCM. This integration strengthens TCM's legitimacy within global healthcare and drives its innovation and relevance in the age of precision medicine.

**Advanced Therapeutic Methodologies**

The AI era has ushered in a transformative wave of advanced therapeutic methodologies within Traditional Chinese Medicine (TCM), particularly across herbology and acupuncture. These developments represent a significant evolution in how TCM is practised, researched, and validated, blending time-honoured traditions with cutting-edge digital intelligence. In herbology and acupuncture, AI technologies are being employed in:

* Chemical component analysis to identify active ingredients and optimise herbal formulas.
* Pharmacological mechanism exploration to reveal how compounds interact with biological systems.
* New drug discovery, where AI rapidly screens vast libraries of herbal compounds to uncover potential therapeutic agents.
* Quantitative and qualitative herb analysis, improving quality control and ensuring consistency in herbal products.
* Herb classification and identification using image recognition and machine learning to differentiate species and detect adulterants.
* Chemical profiling and standardisation, establishing precise molecular fingerprints that support regulatory approval and clinical reliability.
* AI-assisted acupoint selection, where algorithms analyse patient data to personalise point combinations and stimulation protocols.
* Outcome prediction and feedback systems evaluate treatment efficacy in real-time and refine protocols dynamically.
* Robotic acupuncture, a cutting-edge frontier integrating robotics and AI to perform needling procedures with high precision and consistency, is particularly useful in research, remote care, and standardised training environments.

Together, these innovations are driving the modernisation of TCM, enhancing its scientific credibility, improving therapeutic outcomes, and making it more adaptable to the expectations and standards of modern healthcare systems worldwide. Far from replacing traditional methods, AI serves as a powerful ally, amplifying the depth, precision, and accessibility of TCM while preserving its holistic essence.

**Personalised Medicine**

Artificial Intelligence (AI) enables a truly personalised model of care in Traditional Chinese Medicine (TCM), aligning deeply with its core philosophy of individualised treatment. AI customises therapies by analysing patient-specific data, including constitutional type, symptom profiles, medical history, and lifestyle patterns. By cross-referencing this information with extensive clinical databases, AI systems can recommend highly tailored herbal formulations and acupuncture protocols. These personalised treatment strategies integrate traditional diagnostic principles—pattern differentiation and syndrome categorisation—with biomedical data, such as lab results and physiological measurements. This hybrid approach enhances the accuracy and efficacy of treatment, ensuring that therapeutic decisions reflect each individual's unique nature while meeting modern standards of evidence-based care. In doing so, AI reinforces TCM’s holistic foundation while elevating it through precision medicine.

**Digital Infrastructure**

Modernising Traditional Chinese Medicine (TCM) requires establishing a robust digital infrastructure. At the heart of this transformation is artificial intelligence (AI), which is empowered through integrated databases and digital repositories that systematically organise and preserve herbal knowledge, classical formula archives, and clinical case studies. These resources are enriched through knowledge graph construction, which structures and visualises the intricate relationships between symptoms, syndromes, herbs, and treatment strategies. Furthermore, interoperability with Western medical databases and contemporary health information systems allows TCM to engage in meaningful dialogue with global medical standards. This shared knowledge ecosystem not only ensures consistency, accessibility, and scalability of TCM data but also fosters international collaboration, enabling TCM to be scientifically validated, widely disseminated, and effectively integrated into modern healthcare systems.

**Facilitating Globalisation and Standardisation**

AI has become an essential enabler for the international expansion and scientific validation of Traditional Chinese Medicine (TCM), facilitating its globalisation and standardisation. AI helps establish universally accepted diagnostic and treatment protocols by transforming experiential knowledge into data-driven, evidence-based practices. This enhances credibility within international medical communities and allows TCM to be more seamlessly integrated into modern healthcare systems across different cultures and regulatory environments.

AI does not replace the human insight, intuition, or philosophy behind Traditional Chinese Medicine. Rather, it amplifies and refines these elements. By integrating classical principles with modern computational power, AI ensures that TCM survives and thrives in the 21st century—smarter, safer, and more accessible than ever.

## Part 8: The Future of Healing — Where Ancient Wisdom Meets Intelligent Innovation

Artificial Intelligence (AI) offers transformative potential for Traditional Chinese Medicine (TCM), ushering in a new era where ancient wisdom is revitalised through cutting-edge technology. Integrating AI into TCM is not merely an enhancement but a paradigm shift. AI improves diagnostic accuracy, accelerates research, refines treatments, and facilitates global access to TCM by making it more precise, personalised, and evidence-based.

This book, *The Integration of AI in TCM*, has explored the profound synergy between these two worlds. Throughout its chapters, we have examined how AI reshapes TCM across multiple dimensions, including:

* **Standardising Diagnosis**: By transforming subjective methods such as tongue and pulse diagnosis into objective, measurable data, AI supports consistency, reproducibility, and international standardisation.
* **Unlocking New Avenues in Research**: Through technologies like natural language processing, knowledge graphs, and deep learning, AI enables the mining of classical texts, the discovery of novel compounds, and the mapping of herb-disease relationships, breathing new life into traditional knowledge.
* **Innovating Treatment Strategies** and **Enhancing Clinical Practice**: The book has examined AI’s role in TCM prescription generation, objective efficacy assessment, personalised medicine, decision-support tools, and the broader modernisation of TCM in alignment with contemporary medical standards. AI personalises herbal and acupuncture therapies based on a patient’s constitution, medical history, and clinical data, while robotic acupuncture and algorithmic formula optimisation offer unprecedented precision and adaptability.

At its core, this integration signals a future where tradition and technology do not compete but collaborate, each strengthening the other. AI is not a replacement for the TCM practitioner, but a powerful ally that amplifies human insight with data-driven clarity and predictive power. Ultimately, the integration of AI and TCM has the potential to revolutionise healthcare in China and globally.

In conclusion, integrating Artificial Intelligence into Traditional Chinese Medicine represents a practical and forward-thinking evolution of healthcare. AI offers valuable tools that complement and strengthen TCM's core principles by enhancing diagnosis, supporting research, improving clinical outcomes, and enabling personalised treatments. As digital infrastructure grows and technologies advance, this integration has the potential to make TCM more accessible, evidence-based, and globally relevant. The future of TCM lies not in replacing tradition, but in equipping it with the tools to thrive in a modern, data-driven world.

AI-TCM Integration: The Convergence of AI And TCM

|  |  |  |
| --- | --- | --- |
| **Aspect** |  |  |
| **Diagnosis** |  |  |
| **AI-Enhanced Four Diagnostic Methods** | Artificial Intelligence is being used to digitise and standardise traditional TCM diagnostic methods—observation, listening/smelling, inquiry, and palpation. Advanced sensors and AI algorithms analyse data such as pulse, tongue images, and facial features to provide objective health assessments, supporting practitioners in their diagnoses. |
| **AI Pulse Diagnosis** |  |
| **AI Tongue Analysis** |  |
| **AI Face Reading** |  |
| **Syndrome Differentiation** | **Disease Syndromes and Symptoms**  **Differential Diagnosis** |
| **The Future of TCM Diagnosis** |  |
| **Ancillary TCM Diagnosis** |  |
| **TCM-NP** |  |
| **Research** |  |  |
| **Databases** |  |
| **AI-Based Data Mining** | **TCM literature and databases** |
| **TCN Knowledge Acquisition and Novel Knowledge Validation** |  |
| **Knowledge Graph Construction** |  |
| **Chinese Medicine Network Research** |  |
| **TCM Repository** |  |
| **Herbology** |  |  |
| **Chemical Analysis** | **Chemical data analysis** |
| **The Classification and Recognition of Herbs** | **AI for Herbal Identification and Quality Control**  Computer vision and machine learning techniques are employed to identify medicinal herbs, assess their quality, and monitor authenticity, ensuring consistency and safety in herbal medicine rapidly and accurately. |
| **Formula Discovery** | **Personalised Herbal Formulations**  By analysing patient data, AI algorithms can suggest personalised herbal formulations that cater to individual genetic profiles and health conditions, enhancing the efficacy of treatments. |
| **Drug Discovery** |  |
| **Pharmacological Analysis** |  |
| **Herbal Screening** |  |
| **AI-Enhanced Network Pharmacology** |  |
| **Acupuncture** |  |  |
| **AI-Directed Acupuncture** |  |
| **Acupoint Selection** |  |
| **Acupoint Prescription and Combination** |  |
| **Acupuncture Manipulation** |  |
| **Acupuncture Efficacy** |  |
| **Robotics** |  |  |
| **TCM Bots** |  |
| **AI-Driven TCM Robots** | Robotic systems equipped with AI can perform comprehensive TCM diagnostics by analysing pulse, complexion, and tongue coating. These robots compare collected data with healthy individuals to formulate reports detailing specific physical conditions and treatment plans within the TCM framework. |
| **Robotic Acupuncture** |  |
| **Language Models** |  | These large language models are specifically trained on extensive TCM literature, including classical texts and clinical records. They assist in syndrome differentiation, treatment planning, and knowledge retrieval, effectively bridging the gap between ancient wisdom and modern clinical practice. |
| **Chat GPT – Acupuncture Master** |  |
| **Tianyi** | A 7.6-billion-parameter large language model (LLM) specifically designed for TCM. Tianyi is trained on diverse TCM corpora, including classical texts, expert treatises, clinical records, and knowledge graphs. Assists in syndrome differentiation, treatment planning, and knowledge retrieval, effectively bridging the gap between ancient wisdom and modern clinical practice. |
| **OpenTCM** | An LLM-based system that combines a domain-specific TCM knowledge graph with Graph-based Retrieval-Augmented Generation (GraphRAG). Facilitates high-fidelity ingredient knowledge retrieval and diagnostic question-answering without model fine-tuning. |
| **Qibo** | A large language model tailored for TCM was trained using a two-stage approach combining continuous pre-training and supervised fine-tuning. It excels in TCM consultation tasks and demonstrates significant performance boosts in subjective and objective evaluations. |
| **Other** |  |  |
| **TCM Bots** |  |
| **TCM Prescription** |  |
| **Clinical Efficacy** |  |
| **Objective Measurement** |  |
| **Personalised Medicined** | **Tailored Treatment Plans** |
| **Digital TCM** |  |
| **China's Digital TCM Strategy** | A national initiative aiming to integrate emerging digital technologies such as big data and AI into the entire chain of TCM. Establish unified TCM data standards, strengthen data security, and cultivate TCM professionals with digital skills. |
| **Digital Chinese Medicine Research** | An emerging interdisciplinary field developed from TCM and information science, focusing on integrating digital technologies into TCM practices. System architecture and technologies of public service platforms for TCM, including cloud computing and the Internet of Things. |

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