Preprints.org

Article

Not peer-reviewed version

SCMtalk: IoT-Based Scientific Chinese Medicine Pharmacy

Hsing-Hsin Huang and Yi-Bing Lin *

Posted Date: 19 August 2024

doi: 10.20944/preprints202408.1336.v1

Keywords: internet of things; pharmacy actuator; pharmacy sensor; smart medicine; scientific Chinese medicine (SCM); traditional Chinese medicine (TCM)

Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

SCMtalk: IoT-Based Scientific Chinese Medicine Pharmacy

Hsing-Hsin Huang [1] and Yi-Bing Lin [2,*]

[1] Department of Mechanical Engineering, Chung Yuan Christian University
[2] Department of Computer Science, National Yang Ming Chiao Tung University, Taiwan; jasonyblin@gmail.com (Y.-B.L.)
* Correspondence: jasonyblin@gmail.com (Y.-B.L.)

Abstract: Traditional Chinese medicine requires decoction and consumption, which is time-consuming and labor-intensive. Scientific Chinese medicine (SCM), on the other hand, uses concentrated granules that can be taken with hot water, making it widely welcomed. With the widespread adoption of SCM, the packaging technology has started to receive attention. Whether it is manpower allocation, operation time, or the uniformity and residue of the medicine powder, these factors can become bottlenecks in the process. A traditional SCM pharmacy machine is purely mechanically hardwired. This paper proposes SCMtalk, an Internet of Things (IoT)-based SCM mechanism designed to enhance the efficiency and accuracy of SCM medicine packets generation. We show how SCMtalk develops IoT hardware and software modules for medicine selection, mixing, dispensing, packaging, and cleaning. We also explain how the mechanical IoT hardware is integrated with the corresponding software module to become an individual IoT device. These IoT devices can be transparently replaced, allowing us to easily upgrade the individual components of the SCM packet generation through the IoT concept. Finally, we address quality control issues by leveraging IoT. One contribution of this paper is to introduce an interesting SCM application to IoT experts and to demonstrate how we collaborated with pharmacists and mechanical experts to use a powerful IoT platform to create a smart pharmacy.

Keywords: internet of things; pharmacy actuator; pharmacy sensor; smart medicine; scientific Chinese medicine (SCM); traditional Chinese medicine (TCM)

1. Introduction

Traditional Chinese medicine (TCM) is the medical system that originated in ancient China, placing significant emphasis on individual differences and considering factors such as personal constitution and seasons. For the same illness, TCM may prescribe different treatment methods and medications for different individuals. KingNet National Internet Pharmacy [1] compares Chinese and Western medicine, stating that "TCM treats the root cause, while Western medicine treats the symptoms."

Chinese herbal medicine has long been an essential medium for disease treatment, prevention, and health maintenance for the Chinese people. Several studies [2,3] have compared the treatment approaches of TCM traumatology and Western rehabilitation medicine, elucidating the concept that "TCM excels in healing, while Western medicine excels in diagnosis." In recent years, the global spread of the COVID-19 virus has severely impacted human health, leading to increased attention to the healing and immune-boosting functions of TCM.

Chinese herbal medicine is defined according to TCM theory [4,5] and is used to diagnose, treat, alleviate, or prevent human diseases [6]. The materials for Chinese herbal remedies are sourced from the natural world, encompassing minerals, plants, and animal-derived raw materials, as well as processed products and herbal decoctions [7]. TCM traditionally involves the decoction of herbs to allow the elements within them to dissolve into water, creating a medicinal liquid. However, the decoction process is time-consuming, and carrying the medicinal liquid can be inconvenient. With

© 2024 by the author(s). Distributed under a Creative Commons CC BY license.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

the gradual popularization of TCM treatment, traditional herbal decoctions are gradually being replaced by scientific Chinese medicine (SCM). In Chinese societies, SCM is not directly ground from raw herbs but is produced through the collection of herbal materials, decoction, and baking, significantly improving the efficiency of Chinese medicine consumption.

In recent years, SCM has gained acceptance among consumers. Once patients obtain a prescription from a hospital or clinic, they visit a pharmacy to collect their SCM packets. In this paper the term "packet" represents a paper bag filled with medicine powder. Pharmacists measure out the prescribed amount of powdered medicine from various SCM bottles, mix them, and then package and seal them into multi-day doses, adhering to medical instructions. However, this process is typically manual, tedious, and error-prone. To resolve this issue, this paper proposes SCMtalk for smart SCM pharmacy, an Internet of Things (IoT)-based SCM mechanism designed to enhance the efficiency and accuracy of SCM medicine packet generation.

This paper is organized as follows. We first describe the SCMtalk architecture based on IoT, then elaborate on the IoT software modules for medicine selection, mixing, dispensing, packaging, and cleaning, and explain how these software modules interact with the mechanical hardware. Finally, we address quality control and packaging speed issues, making significant contributions to these challenges by leveraging IoT.

2. Related Work

The typical medical visit process includes four steps: registration, physician consultation, prescription processing, and medication pickup. SCM diagnostic technology for physician consultation aligns with modern traditional Chinese medicine principles, emphasizing dataization and objectification. By employing image acquisition, spectral analysis, machine learning [8–11], and text-based prescription generation [12], SCM aims to quantify and standardize diagnostic methods, reducing human interference and enhancing traditional Chinese medicine through modern technology. A good example [13] explores the standardization and digitalization of nine traditional Chinese medicine constitutions, emphasizing tongue diagnosis and consultation. It introduces a tongue detection method and a questionnaire-based diagnosis system, demonstrating effectiveness through experimental results and practical application development. SCMtalk will follow approaches similar to the above studies to generate prescriptions for Chinese medicine.

Due to the extensive variety of Chinese herbal medicines, effectively managing medications to avoid errors in dispensing and pickup is a crucial consideration. Concerning the medication pickup stage, a method was proposed [14] to improve the arrangement system of Chinese medicine jars, aiming to shorten the time pharmacists spend retrieving medications by adopting a more efficient canister arrangement. The study in [15] analyzes medication dispensing error records from various hospital pharmacy departments, identifying the similarity in medicine names as a primary factor contributing to dispensing errors. To enhance accuracy in dispensing, the authors in [16] suggested an integrated intelligent pharmacy management system capable of reading prescription information, scanning the two-dimensional barcode on the medicine canister to confirm alignment with the prescription, thus preventing errors. Although SCMtalk is a fully automated mechanism, barcodes, as demonstrated in [16], are still employed to prevent front-end drug misplacement issues, thereby avoiding errors, saving manpower, and reducing operation time.

A medicine dispensing verification structure was introduced in [17] and a prescription display device, integrated into a Chinese medicine dispensing verification system. This system first enhances the barcode structure on medicine jars to include information such as product number, batch number, and expiration date. In addition to performing item checks and confirming dispensing quantities, it also controls the expiration date and batch number of medications, enhancing medication safety. When the system reads prescription information, it signals the corresponding medication cabinet to assist pharmacists in quickly identifying the storage compartment for the medication, preventing the occurrence of medication mix-ups.

To cope with the increasing number of patient visits, Chinese hospitals, clinics, and pharmacies have begun using automatic medicine packaging machines [18]. These devices consist of two main

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

parts: dispensing and packaging. The dispensing area has multiple slots where pharmacists manually flatten the medicine powder in the slots before using a mechanism to transfer the powder into dispensing slots and convey it to the drop point. The packaging area features a medicine funnel that guides the powder into medication paper, which is then heat-sealed for packaging. Since the action of flattening the powder relies solely on the senses and experience of healthcare personnel, it often leads to uneven distribution of medication. Additionally, the dispensing mechanism has many gaps and blind spots that are challenging to clean, causing potential issues of residual medication and cross-contamination.

The studies in [14–18] only implemented partial functions of SCMtalk for intelligent pharmacy and did not utilize the advanced IoT technologies. Specifically, the aforementioned medication dispensing and machines need to accommodate the back-and-forth movement of the dispensing mechanism, occupying at least twice the space of the dispensing mechanism alone, causing inconvenience for small clinics or pharmacies. To reduce space, the authors in [19] proposes a circular automated powder distribution machine that aims to evenly distribute powder while minimizing its size. A similar design [20], installs all the medicine powder boxes on a conveyor belt. After the pharmacist flattens the powder in the slot, it is directly poured into the powder box. The conveyor belt moves the powder box to a fixed dispensing point, facilitating the subsequent packaging process. The advantage of this design is that the dispensing mechanism does not need to move, helping reduce the size of the packaging machine. The downside of this approach is its heavy reliance on manual labor, which leads to the machine lacking the ability to communicate with the external environment. Furthermore, it cannot interface with other production stages to form a complete automated system.

The application of a spiral mechanism in a Chinese medicine packaging machine was also discussed [20]. The device uses a discharge unit with a spiral part to extract medicine powder from a bucket above, and a weighing scale measures the weight of the bucket to determine the dispensing quantity. Since SCM contains a higher starch content and is prone to clumping when exposed to air, using a spiral mechanism to transport the powder often results in blockages and residue due to powder condensation within the mechanism, making it difficult to clean. Based on the above analysis, it is evident that the screw mechanism is not suitable for sticky SCM, making it even less suitable for developing a fully automated system.

The studies in [14–20] exclusively concentrate on managing individual sections within the prescription of SCM. They do not comprehensively discuss how to enhance overall operational efficiency. Furthermore, these studies entirely overlook the advantages offered by IoT technology, leading to a waste of manpower and time that cannot be compared with the benefits brought by SCMtalk.

3. SCMtalk: IoT-Based SCM Packet Generation

Figure 1 illustrates the SCMtalk architecture, which comprises four major mechanisms: the powder selection mechanism (Figure 1 (1)-(7)), the mixing and cleaning mechanism (Figure 1 (8)-(10)), the dispensing mechanism (Figure 1 (12)), and the packaging mechanism (Figure 1 (13)). The dispensing and packaging mechanisms and the SCMtalk server are installed in a cabinet, with dimensions approximately 53 cm (W) × 40 cm (L) × 120 cm (H).

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

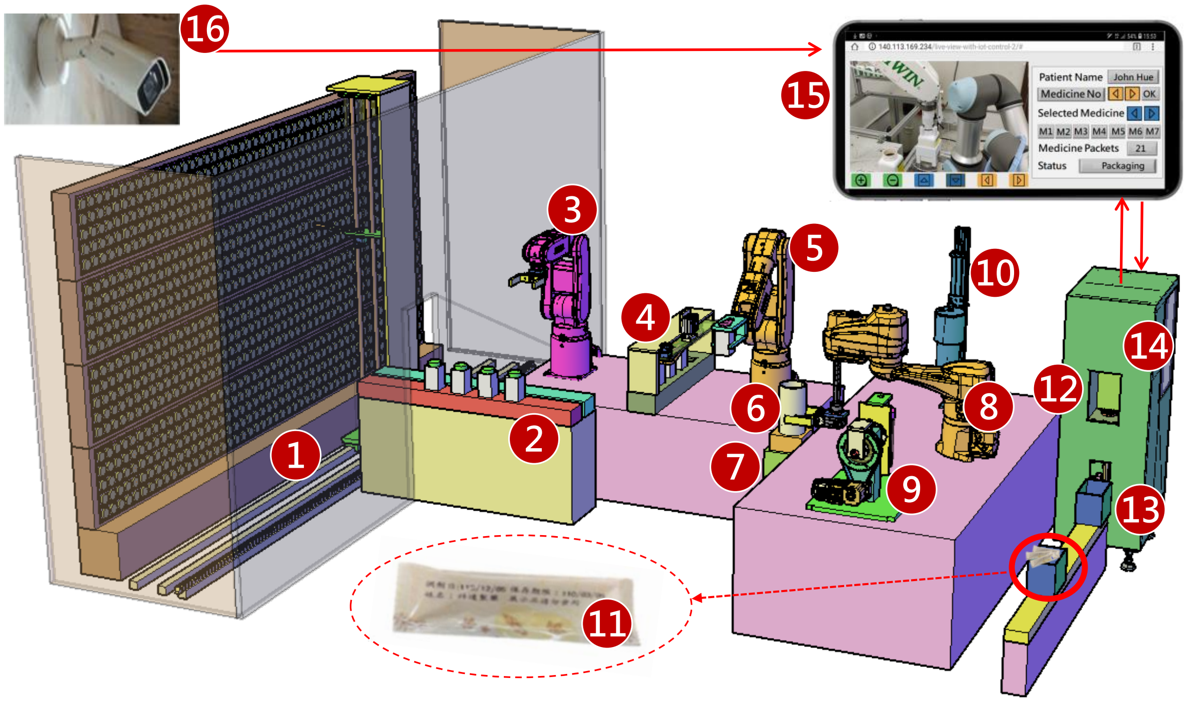

Figure 1. The SCMtalk architecture.

Through these mechanisms, the SCM powders are packaged into packets (Figure 1 (11)). The powder selection mechanism includes a cylindrical medicine jar with a built-in piston (Figure 1 (6)). Before use, the cylindrical medicine jar needs to be filled with pre-mixed medicine powder from the selection mechanism.

The above four major mechanisms are considered as IoT devices managed by an IoT platform called IoTtalk [21], which is installed on the SCMtalk server in the dispensing and mixing cabinet. In addition to the on-site touch panel (Figure 1 (14)), SCMtalk also supports a remote control board that can be accessed from any mobile device with a web browser (Figure 1 (15); see also Figure 3). The browser has a video screen that allows the pharmacist to remotely monitor SCMtalk operations through a camera (Figure 1 (16)).

The top screen of the dispensing and packaging machine (Figure 1 (14)) serves as a multifunctional control interface, capable of displaying the current operational status of SCMtalk. The middle loading port (Figure 1 (12)) is the entrance of the dispensing mechanism, where the robot arm (Figure 1 (8)) places medicine jar (Figure 1 (6)). Below it is a temperature display for operators to monitor the current temperature, though not shown in the figure. Beneath is the outlet for medicine packets (Figure 1 (13)), and upon completion of the automated process, the packets (Figure 1 (11)) can be retrieved from the lower outlet. Through the application of vertical packaging technology, the quantity of packets per prescription can reach up to 100, surpassing all other packaging machines on the market. Details of the dispensing and packaging mechanisms in the cabinet will be provided in Figure 4.

SCMtalk provides a web-based graphical user interface (GUI; Figure 2 (1)) for configuring IoT devices, accessible and manipulable through the touch panel of SCMtalk (Figure 1 (14)) or the web browser of any mobile device. To be managed by SCMtalk, every IoT device is equipped with two software modules: the sensor and actuator application (SA) and the device application (DA). The SA implements the IoT functions of the device. For example, the control board SA incorporates various web-based functions, such as displaying the patient's name (Figure 3 (1)), providing medication instructions (selection of medicine powder bottles; Figure 3 (2)), and indicating the number of medicine packets to be produced (Figure 3 (3)). The GUI also presents the status of SCMtalk operations, including the status itself (Figure 3 (4)), and other information not shown, such as medication package length and the current number of generated packages. The control board also

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

features a real-time video streaming view window (Figure 3 (5)), enabling the pharmacist to control zooming and the view angle of the camera (Figure 3 (6)).

The DA serves as an interface for an IoT device to interact with the SCMtalk server. For each IoT device, the input data from the sensors/controls to be sent to the server is represented by small icons grouped under a device icon located on the left side of the GUI window. For instance, the inputs in Figure 3 (1)-(3) are represented as small icons Patient-I, medicine-I and PacketNo-I within the Control Board icon (Figure 2 (2)).

These small icons, with names appended with "-I," are referred to as input device features (IDFs). The instructions or status information sent from the SCMtalk server to the IoT device is represented by icons placed on the right side of the GUI window. For example, the output status indicator (Figure 3 (4)) is grouped within the status-O icon in Figure 2 (3). The small icons with names appended with "-O" are termed output device features (ODFs). SCMtalk configuration is achieved by connecting the IDFs to the ODFs of the IoT devices.

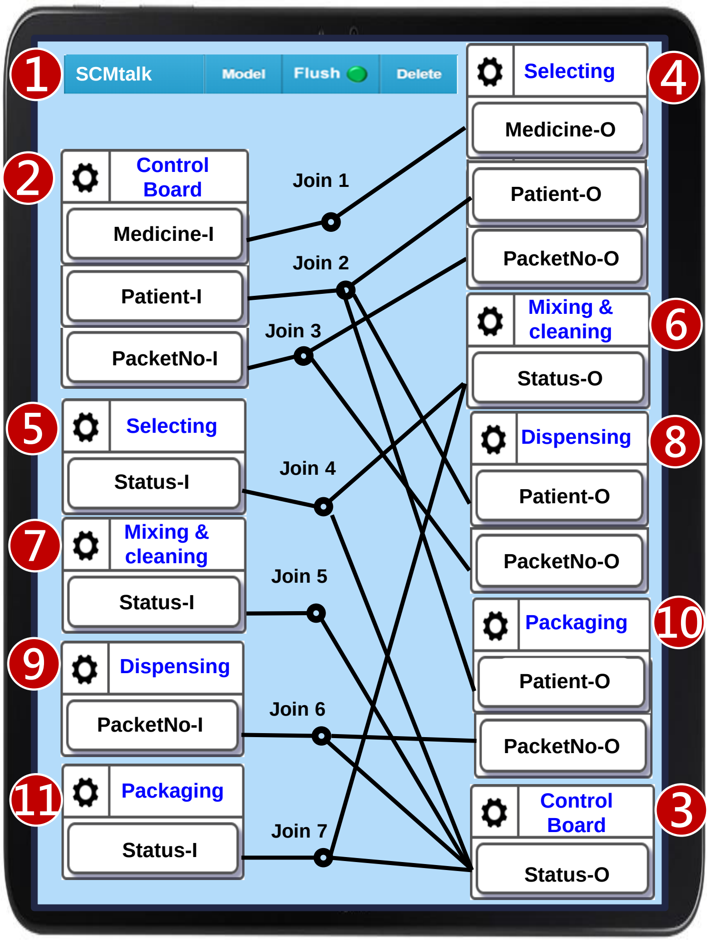

Figure 2. The SCMtalk configuration.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

Figure 3. The control board.

In Figure 1, the pharmacist uses the control board to provide the medicine instructions to the selection mechanism, which are achieved through the Join links 1-3 in Figure 2. The cabinet robots put the selected medicine powders for N packets (specified by PacketNo-I through Join 3; see Figure 2 (2)→(4)) into the cylindrical medicine jar (Figure 1 (6)), and instruct the mixing mechanism to mix the powders and report the status to the pharmacist through Join 4 (Figure 2 (5)→(3)). After the powders are mixed, the dispensing mechanism is alerted through Joins 2 and 3 (Figure 2 (2)→(8)) to perform the medicine dispensing action for N packets (to be elaborated in Figure 4). When dispensing for the n-th packet is complete ($1 \leq n \leq N$), the packaging mechanism is alerted through Join 6 (Figure 2 (9)→(10)). When dispensing for the N-th packet is complete, the control board is alerted through Join 7 (Figure 2 (11)→(3)), and then the cleaning mechanism is also alerted through Join 7 (Figure 2 (11)→(6)) to clean the medicine jar.

4. The Selection and Mixing Mechanisms

Figure 1 (1)-(7) depict the selection mechanism, and its DA software module is represented by two icons in the SCMtalk GUI (Figure 2 (4) and (5)). Through the control board, the pharmacist generates a prescription specified by the ODFs Patient-O, Medicine-O, and PacketNo-O of the DA (Figure 2 (4)), and the DA of the control board subsequently transmits it to the selection mechanism through Joins 1-3 (Figure 2 (2)→(4)). Then the selection SA software module executes the following steps:

Step S1. The SA invokes the IoT-based medicine cabinet (a 1000-bottle medicine cabinet; Figure 1 (1)) to retrieve multiple medicine bottles based on the prescription. The medicine bottles are sequentially placed on the first conveyor belt (the green belt in Figure 1 (2)) and transport them to the pick-up area.

Step S2. The SA instructs the HIWIN RA605-710 robotic arm (Figure 1 (3)) [22] to use an electric gripper to sequentially grab the medicine bottles and then place them into the automatic capping machine. When all the medicine bottles are placed, the automatic capping machine is activated, lifting the caps upward for temporary storage (Figure 1 (4)).

Step S3. The SA instructs the HIWIN RA605-909 robotic arm (Figure 1 (5)) [23] to use an end effector to sequentially grab the medicine bottles above the medicine jar (Figure 1 (6)), rotate the bottles so that the openings face downward, open the cover on the end effector, and pour the medicine powder into the medicine jar.

Step S4. The medicine jar is placed in the weighing area, below a precision scale (Figure 1 (7)). When the amount of medicine poured from each bottle reaches the preset threshold, the SA notifies the robotic to stop pouring and return the bottle to the automatic capping machine.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

Step S5. The SA checks whether the pouring process for all medicine bottles has been completed. If not, go to **Step S4**.

Step S6. (The pouring process is completed) The SA activates the automatic capping machine to screw the cap downward onto the medicine bottle. Then, the SA instructs the RA605-710 to sequentially pick up the medicine bottles, place them on the second conveyor belt (the orange belt in Figure 1 (2)), and transport them back to the automated medicine cabinet, allowing the cabinet to return the bottles to their original positions.

At the end of **Step S6**, the selection SA alerts the mixing mechanism through the Status-I in the DA (Figure 2 (5); via Join 4). Figure 1 (8)-(10) depict the mixing and cleaning mechanisms, and the mixing and cleaning DA is represented by two icons in Figure 2 (6) and (7) in the SCMtalk GUI. When the Status-O in the mixing DA receives the instruction from Join 4 (Figure 2 (5)→(6)), the following steps are executed.

Step M1. The SA instructs the HIWIN RS410-600-200 robotic arm (Figure 1 (8)) [24] to use its electric gripper to pick up the filled medicine jar and place it into the mixing machine (Figure 1 (9)).

Step M2. After the mixing process is complete, the SA instructs RS410-600-200 to move the mixed medicine jar to the entrance of the dispensing mechanism (Figure 1 (12)).

Step M3. The SA reports the complete status to the control board through the Status-I of its DA (Join 5; Figure 2 (7)→ (3)) and waits for the next instruction.

Step M4. When the powder in the medicine jar is consumed, Status-O of the DA receives the packaging complete instruction from Join 7 (Figure 2 (11)→ (6)), and the SA instructs the RS410-600-200 robot to move the empty medicine jar to the cleaning machine (Figure 1 (10)).

Step M5. The SA instructs the cleaning machine to clean the jar. After cleaning, the SA instructs the RS410-600-200 robot to move the empty jar to the weighing area (Figure 1 (7)). Then, the SA reports the cleaning complete status to the control board through Join 5 (Figure 2 (7)→ (3)).

5. The Dispensing Mechanism

Figure 4 (a) depicts the details of the dispensing mechanism in Figure 1 (12), and its DA is represented by two icons in Figure 2 (8) and (9). When Patient-O and PacketNo-O in the DA of the dispensing mechanism receive the name of the patient and the number of medicine packets from the control board through Joins 2 and 3 (Figure 2 (2)→ (8)), the dispensing S A executes the following steps:

Step D1. The SA initializes parameters and returns all motors (Figure 4 (1)-(3)) to the starting point.

Step D2. After **Step M3** is complete, the medicine jar filled with powder (Figure 4 (4)) is placed on the linear module (Figure 4 (3), (5) and (7)), which triggers the sensor at the feeding port (Figure 4 (5)) to activate the SA to execute **Step D3**.

Step D3. The SA instructs the linear module to raise the powder until it is pressed against the upper cover of the dispensing port (Figure 4 (6)). The linear module is located below, including a ball spline (Figure 4 (7)) driven by a servo motor (Figure 4 (3)) and a coupling mechanism (Figure 4 (5)) for the medicine jar.

Step D4. In the pressure module (Figure 4 (1) and (6)), the upper cover plate contains a load cell (Figure 4 (6)); when the pressure sensor detects that pressure reaches the preset value, the pressing stops. The SA instructs the linear motor (Figure 4 (1)) to move the upper cover plate upward, simultaneously recording the piston position to determine the height Y of the powder in the jar. The SA divides Y by the total packet number N obtained from PacketNo-O to compute the lifting height H required for each scraping.

Step D5. The SA starts the scraping process for the n-th packet ($1 \leq n \leq N$) by raising the powder to height H, activating the scraper module (Figure 4 (2) and (9)) to push the powder into the funnel (Figure 4 (8)), guiding it into the packaging mechanism (Figure 4 (b)).

Step D6. Figure 4 (d) illustrates the scraping operation of the blade (Figure 4 (9)). Before the rise of the medicine powder, the cover plate and the blade are at the origin ((16) in Figure 4 (d)). When the medicine powder rises and exceeds the preset pressure value, the blade moves counter clock-wise

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

to pour the powder to the funnel ((17) in Figure 4 (d)). More details of the scraper module will be elaborated later.

Step D7. The SA instructs the packaging mechanism to handle the n-th packet through PacketNo-I of the DA (Join 6; Figure 2 (9)→ (10)).

Step D8. If $n < N$, the SA executes **Step D5** again. Otherwise, the dispensing process is complete.

The scraper module merits further discussion. This module is located above the medicine jar, consisting of a scraper (Figure 4 (9)) driven by a motor (Figure 4 (2)) to pour the powder into the funnel (Figure 4 (8)) below. The inner edge of the powder funnel is inclined to slow down the powder's falling speed, preventing dust.

During the initialization of SCMtalk, the scraper module is calibrated with four parameters to ensure optimal performance: the amount of powder ascent, scraper speed, surface adhesion of the scraper and the bottom plate, and the nature of the funnel surface. These parameters must be carefully managed to ensure the uniformity of the medicine packaging. Through experiments, we found that powder does not uniformly conduct pressure and is easily influenced by the nature of the powder, to leading uneven distribution of medicine powder density inside the medicine jar. We improve the uniformity control with the following setups:

U1. Accurately grasp the precision of the linear module's ascent to reduce the phenomenon of uneven medicine dispensing caused by mechanical errors.

U2. Adjust the contact area between the scraper and the bottom plate of the scraper module, ensuring parallel contact to prevent uneven locking of the scraper before (Figure 4 (16)) and after (Figure 4 (17)), which may lead to the distortion of the scraper and result in uneven scraping and, consequently, uneven packaging.

U3. During processing, polish and grind both the funnel surface and the scraper module 's bottom plate to ensure a smooth surface. Simultaneously, coat the cuter layer with Teflon to reduce powder adhesion.

U4. Due to the starch granules present in the medicine powder, excessive compression can lead to the fragmentation of the powder, thereby affecting its properties. It is necessary to conduct preliminary pressure experiments to determine the appropriate pressure by observing the compression behavior of the medicine powder. This pressure value will be established as a benchmark and set as the pressure threshold for the load cell of the cover plate above the medicine jar.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

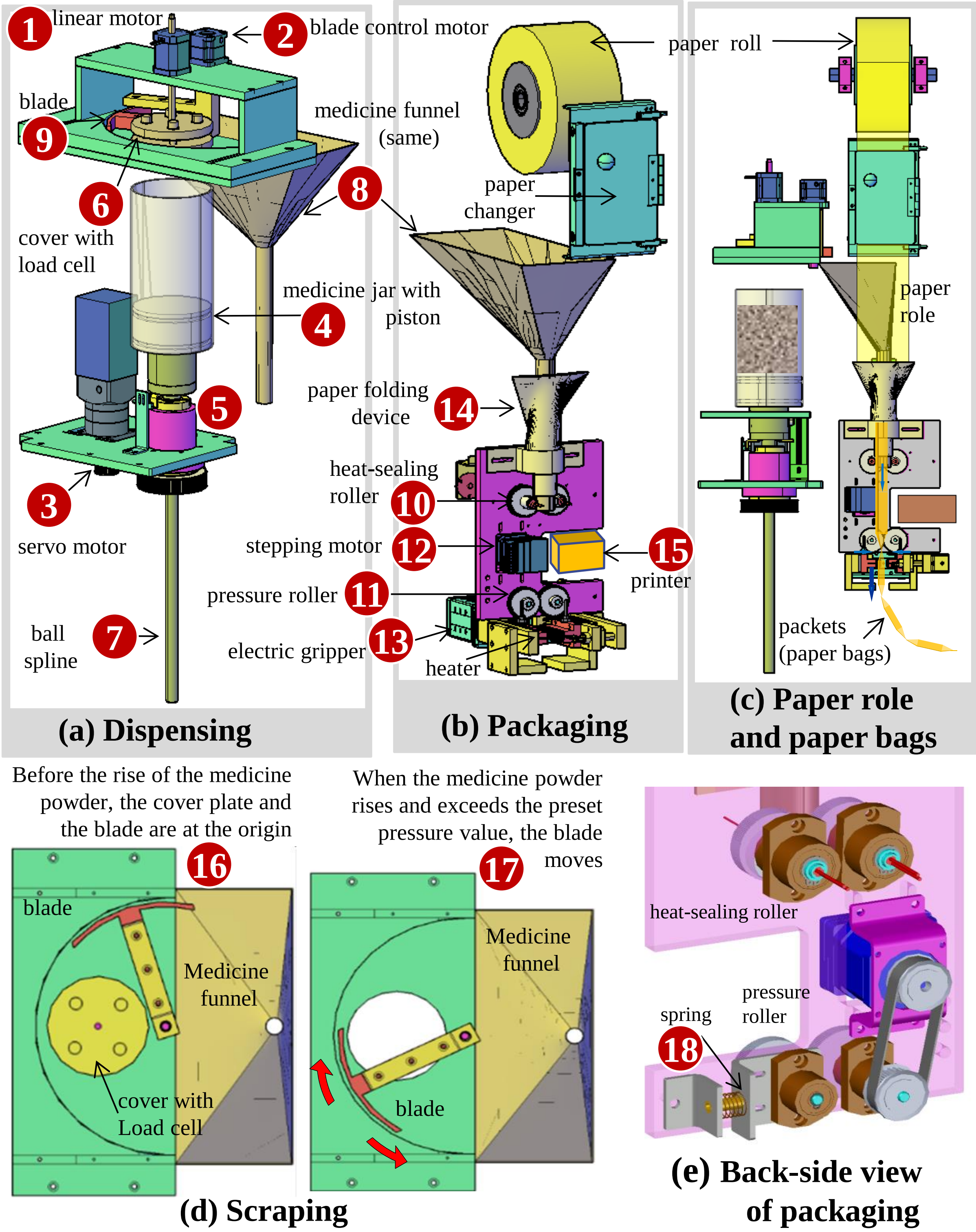

Figure 4. The dispensing and packaging mechanisms.

6. The Packaging Mechsnism

Figure 4 (b) depicts the details of the packaging mechanism in Figure 1 (13), and Figure 4 (c) illustrates how the paper roll is manipulated to produce the paper bags. The packaging DA is represented by two icons in Figure 2 (10) and (11). When the Packaging Patient-O in the DA receives the patient's name from Join 2 (Figure 2 (2)→ (10)), the packaging SA executes the following steps:

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

Step P1. The SA initializes the heat-sealing rollers (Figure 4 (10)) and the pressure rollers (Figure 4 (11)). The pressure rollers, controlled by a stepper motor (Figure 4 (12)), regulate the speed of paper feed and the length of the medicine packet, which can range from 1 to 14 centimeters. The heat-sealing roller is responsible for sealing the side of the medicine bag.

Step P2. The SA directs the pressure roller to pull the paper down through the paper folding device (Figure 4 (14)), ensuring that the paper becomes the shape of the medicine bag. The heat-sealing rollers seal the side of the medicine bag, while the bottom seal is handled by an electric parallel griper (Figure 4 (13)). This griper can drive a V-cut blade mechanism on both sides with heat-sealing blocks, facilitating the sealing and cutting of the bottom edge of the medicine bag. A printer (Figure 4 (15)) is situated between the heat-sealing and the pressure rollers, enabling the printing of prescription information on the medicine bag.

Step P3. The completed, sealed medicine packet slides to the discharge outlet and falls into the pre-set medicine basket to be moved by the conveyor belt of the packaging mechanism (Figure 1 (13)). The SA reports the status to both the dispensing mechanism and the control board through Join 7 in Figure 2.

In **Step P2**, the tightness of the seal of the medicine packet determines the preservation time of the medicine powder. Especially in the case of TCM composed of starch, exposure to air can cause the medicine powder to clump due to humidity, affecting the quality of the medicine powder. Therefore, the purpose of testing the seal tightness is to effectively preserve the medicine powder and prevent it from being affected by external environmental factors.

To enhance the tightness of the packaging, a spring mechanism (Figure 4 (18)) is installed on the back side of the pressure roller (Figure 4 (11)) in the medicine packaging mechanism, with the aim of utilizing its compressive ability to provide pressure for sealing. After actual testing, it was observed that in our original design, uneven force caused the inclination of the mechanism, leading to the unstable rotation of the rollers and resulting in uneven packaging and poor seal tightness. Such a design easily leads to leakage or rupture of the medicine packet. Another experiment revealed that excessive pressure could cause over engagement of the heat-sealing roller (Figure 4 (10)) and the pressure roller (Figure 4 (11)), leading to the rupture of the paper in the medicine bag. In our final design, we tightened the bearing seat, replaced the spring, selected a spring with lower rigidity to reduce the tilting situation, and ultimately increased the stability of the edge-sealing process.

Other improvements include increasing the flexibility of the medicine bag paper, correcting the lateral distance between the folder device outlet and the heat-sealing roller (Figure 4 (10)) to change the width of the medicine bag sealing. When the edge-sealing of the medicine bag paper is too large, the medicine bag paper may become too tight, causing the motor to be unable to move. When the width of the edge-sealing of the medicine bag paper is too small, it can result in an unreliable seal. The solution is to adjust the spacing between the folder device and the funnel to change the side-sealing width of the folder device, thereby improving the air leakage or excessive resistance of the medicine packet.

7. Quality Control

Besides setups U1-U4, to ensure the uniform quality of every medicine packet, we need to make sure that the weights of the packets are the same. For a prescription, let W_n and V_n be the weight and the volume of the n-th packet. Then $H_n = V_n/A$ where A represents the cross-sectional area of the jar, and $Y = \sum_{n=1}^{N} H_n$. In the perfect condition, $W_n = W_m$ and $H_n = H_m$ for $1 \leq n \neq m \leq N$. Therefore, the theoretical ascent distance for a packet is $H = \frac{Y}{N}$. Unfortunately, when the dispensing SA measures the height Y of the powder in the jar, the linear module (Figure 4 (3), (5) and (7)) applies pressure to the medicine jar, resulting in uneven powder densities within the jar. Figure 5 (a) shows the density distribution in the jar based on our experiments with $H_n = H$. In this figure, the Y-axis represents the density change of the average powder density, and the X-axis represents the percentage of the height of the medicine jar (from the top to the bottom). We also observe the following phenomenon: after mixing the medicinal jars, due to the poor flowability of the powder, it is common to observe a depression around the top. While compression can flatten the central area to some extent, it still cannot completely fill the gaps around the perimeter, resulting in a lower density of medicine at the top. Meanwhile, at the bottom, due to pressure, the density of the medicine is higher.

If we use H as the ascent distance for the n-th packet, then the weights of the produced packets are seriously uneven, as illustrated in Figure 5b. In this figure, the average weight of a packet is 5.63g, but the weights of 19 packets range from 2.432g to 6.06g.

One way to resolve this issue is by installing a precise weight scale to be used in **Step D5** by the dispensing SA. However, the implementation cost is very high, and this weighing process will also decrease the speed of packet production.

Alternatively, we develop a quick approximate method to speed up **Step D5** with acceptable weight accuracy. Based on the historical data, we can derive the density distribution in Figure 5a to obtain the predicted ascent distance $\bar{H}_n$ for the n-th packet. That is, the ascent distance H_n is set to $\bar{H}_n$. At **Step P3**, the discharge outlet has a weight scale that can measure the weight of n packets in the medicine basket. The packaging SA uses the measured data to compute the exact weigh H_n^* of the n-th packet and use it to calibrate the $\bar{H}_n$ value in real time. Specifically, for the l-th patient of the same prescription, $H_{n,l} \leftarrow \bar{H}_{n,l-1}$, and $\bar{H}_{n,l} \leftarrow \frac{H^*_{n,l-1}+(l-1)\bar{H}_{n,l-1}}{l}$. Figure 5c shows the weights of produced packets based on the $\bar{H}_n$ distribution, which are much more even than those in Figure 5 (b). Specifically, the weights of 19 packets range from 5.03g to 6.04g.

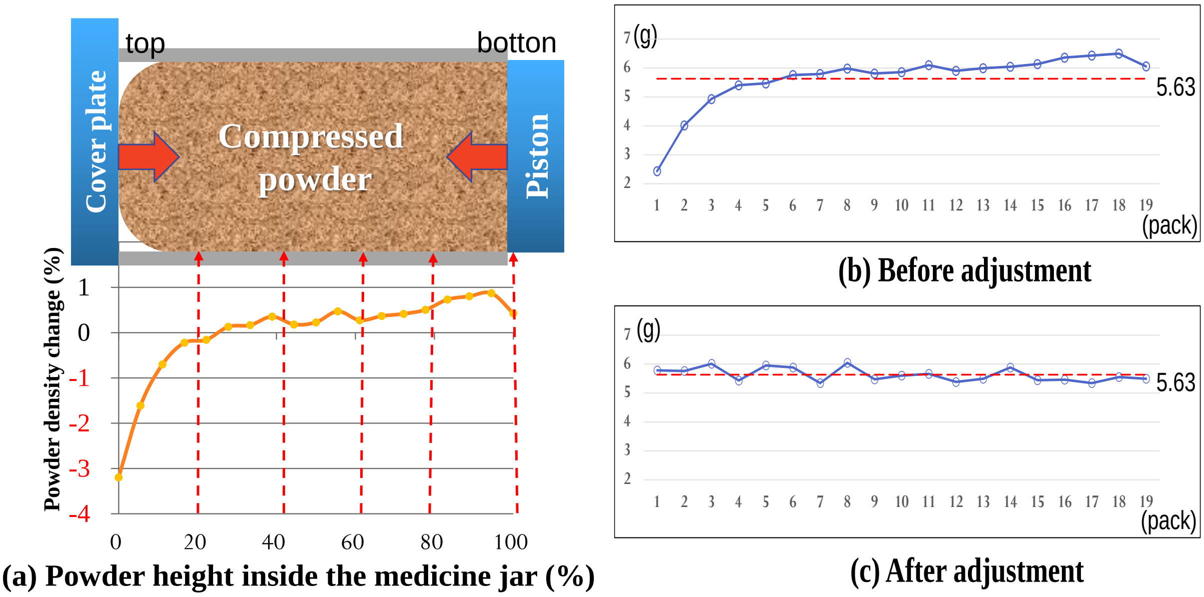

Figure 5. Powder density distribution and weights.

8. Conclusions

This paper unveils how SCMtalk pioneers IoT software modules for Chinese medicine selection, mixing, dispensing, packaging, and cleaning, elucidating the seamless interaction between these software modules and the mechanical hardware. A key focus is on overcoming challenges related to quality control and packaging speed through strategic IoT integration for parallel computing.

SCMtalk operates as a fully automatic system, excelling in its ability to precisely allocate powdered medicine. With an impressive packaging speed of less than 3 seconds, it not only outperforms existing market products but also achieves a remarkable maximum packaging quantity of over 100 bags per prescription. This not only saves considerable time in pre-processing and subsequent cleaning but also establishes a new standard in packet generation speed, demonstrating a significant leap forward compared to current market systems. To further enhance packet generation speed, an analytic model has been developed, conducting mean value analysis to recommend the optimal number of dispensing and packaging machines for parallel processing. SCMtalk, backed by

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

an ROC patent [26], is currently in deployment at China Medical University, marking a milestone in advanced SCM technology. A video [27] illustrates the process in which SCMtalk mixes, dispenses, and packages the SCM powder, and then cleans the jar.

Author Contributions: Hsing-Hsin Huang: Mechanical Platform and Methodology; Yi-Bing Lin: IoT Platform and Methodology.

Funding: This work was supported in part by National Science and Technology Council (NSTC) 112-2321-B-A49-018, NSTC 112-2221-E-A49-049, NSTC 112-2420-H-A49-001, NSTC 112-2634-F-A49-004, NSTC 112-2221-E-033-023, NCKU Miin Wu School of Computing, Quanta and NYCU/NCKU AI Joint Research Center, China Medical University Hospital, Research Center for Information Technology Innovation, Academia Sinica**.**

Conflicts of Interest: The authors declare no conflict of interest.

References

1. X. Qiao, Similarities and Differences Between Traditional Chinese Medicine and Western Medicine, Heyitang Traditional Chinese Medicine Clinic, http://www.tcm.tw/articleview.php?id=2691 (2018)
2. S.-P. Rau, Study on Utilization of Traditional Chinese Trauma Tologic Manipulation and Rehabilitation Medicine in Taiwan, Master's Thesis, Department of Health Management, Asia University (2007)
3. X. Lin, A Comparison of Traditional Chinese Massage and Physical Therapy, NTU Medical Network Health Park, [Online] (2023). Available: https://epaper.ntuh.gov.tw/health/201108/health_1.html
4. P. Chen, Administration of Traditional Chinese Medicine, Department of Chinese Medicine, Ministry of Health and Welfare, [Online] (2019). Available: http://www.tccpa.org.tw/data/1051023.pdf
5. J. J. H. Wang, "Validation, Instrumentation and Procedures in Scientific Traditional Chinese Medicine (STCM)," *2022 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting (AP-S/URSI)*, Denver, CO, USA, 2022, pp. 1076-1077.
6. X. Xie and Y. Cheng, "Design of a Distributed Collaborative Chinese Medicine Treatment Platform," *2022 12th International Conference on Information Technology in Medicine and Education (ITME)*, Xiamen, China, 2022, pp. 198-201, doi: 10.1109/ITME56794.2022.00051.
7. KingNet, Understanding Chinese Medicinal Materials, KingNet National Online Medical Network, [Online] (2020). Available: https://www.kingnet.com.tw/knNew/tcmking/tcmking-herbs.html?medicineid=4
8. L. Wei and P. Zhang, "Intelligent research method of traditional Chinese medicine based on computer vision thinking," *2021 6th International Symposium on Computer and Information Processing Technology (ISCIPT)*, Changsha, China, 2021, pp. 137-140.
9. Z. Zheng, Y. Liu, Y. Zhang and C. Wen, "TCMKG: A Deep Learning Based Traditional Chinese Medicine Knowledge Graph Platform," *2020 IEEE International Conference on Knowledge Graph (ICKG)*, Nanjing, China, 2020, pp. 560-564, doi: 10.1109/ICBK50248.2020.00084.
10. C. Rong, X. Li, X. Sun and H. Sun, "Chinese Medicine Prescription Recommendation Using Generative Adversarial Network," in *IEEE Access*, vol. 10, pp. 12219-12228, 2022.
11. G. Tian *et al*., "Can a Holistic View Facilitate the Development of Intelligent Traditional Chinese Medicine? A Survey," in *IEEE Trans. on Computational Social Systems*, vol. 10, no. 2, pp. 700-713, 2023.
12. C. Duan, "Sequence generation model of traditional Chinese medicine," *12th International Conference on Information Technology in Medicine and Education*, Xiamen, China, 2022, pp. 258-262.
13. Y. Yuan and W. Liao, "Design and Implementation of the Traditional Chinese Medicine Constitution System Based on the Diagnosis of Tongue and Consultation," in *IEEE Access*, vol. 9, pp. 4266-4278, 2021.
14. C.-P. Chiang, Evaluation of the Arrangement System of Medicinal Cup for Chinese Proprietary Medicine, Master's Thesis, Dept. of Industrial Engineering and Management Information, Huafan University (2009)
15. C.-P. Huang, The Analysis of Dispensing Errors caused by Name-Alike and Look-Alike Pharmaceutical Products, Master's Thesis, Department of Health Care Management, Chang Gung University (2006)
16. X. Wang, et al., Integrated Intelligent Pharmacy Management System, Republic of China Patent, Certificate Number: I442255 (2014)
17. C.-H. Chen, The Innovative Path of an Ancient Industry, Lecture at Providence University (2017)
18. F.-Z. Lin, Drug Packing Device, Republic of China Patent, Certificate Number: I247604 (2006)
19. Y.-T. Chen, Powder Allotting Device, Republic of China Patent, Certificate Number: I353950 (2011)
20. W. Cai, Weighing and Dropping Mechanism for Packaged Medicine Machine, Republic of China Utility Model Patent, Certificate Number: M617431 (2021)
21. Y.-B. Lin, Y.-W. Lin, C.-M. Huang, C.-Y. Chih and P. Lin, "IoTtalk: A Management Platform for Reconfigurable Sensor Devices," IEEE Internet of Things Journal, pp. 1552-1562, 2017.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 19 August 2024 doi:10.20944/preprints202408.1336.v1

22. HIWIN, RA605-710-GC Articulated Robot, [Online] (2023). Available: https://www.hiwin.tw/products/mar/articulated/ra605/ra605_710_gc.aspx
23. HIWIN, RA605-909-GC Articulated Robot, [Online] (2023). Available: https://www.hiwin.tw/products/mar/articulated/ra605/ra605_909_gc.aspx
24. HIWIN, RS410 Series Scara Robot RS410-600-200-LU, [Online] (2023). Available: https://www.hiwin.tw/products/mar/scara/rs410/RS410_600_200_LU.aspx
25. Y. -B. Lin et al., "IoT-based Strawberry Disease Detection with Wall-mounted Monitoring Cameras," in IEEE Internet of Things Journal, doi: 10.1109/JIOT.2023.3288603.
26. H.-H. Huang, et al., Vertical Packaging System, Republic of China Patent, Certificate Number: I814607 (2023)
27. SCMtalk: Scientific Chinese Medicine Mixing and Packaging, [Online] (2023). Available: https://www.youtube.com/watch?v=n_KK2pJcvSs

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.