An smart toilet integrated performance detection device combined with machine vision

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Abstract. The traditional smart toilet comprehensive detection device proves unsatisfying on integration, intelligence, time and effort cost, and precision. In order to improve the detection accuracy and efficiency of smart toilets test, and overcome the poor integration of equipment and low intelligence, image processing technology is applied to the comprehensive performance detection equipment for smart toilets in this paper. Lenovo all-in-one computer is used as the upper computer to realize the collection and analysis of key data. Siemens PLC, as a lower-level computer, controls multiple temperature water tanks, frequency converters and pipeline valves, and collects and transmits data on temperature and cleaning power. Meanwhile, CCD camera is innovatively introduced to locate the seat temperature test points on the smart toilet. The test results show that the detection accuracy, efficiency and integration of the device are improved obviously.

1. Introduction
With the continuous development of society, smart toilets have received widespread attention, various products have emerged one after another, and standards have also emerged and are constantly updated[1]. Standard requirements are constantly improving, so testing equipment needs to keep pace with the times. At present, there are many standards related to smart toilets in China, such as: JIS A 4422:2011 "Warm water wash toilet seat", GB/T 34549-2017 "Sanitary ware smart toilet", GB/T 23131-2008 "Electronic Toilets", JG/T 285-2010 "Seat Bidet", CBMF 15-2016 "Smart Toilets"; Energy efficiency and water efficiency standards: GB 38448-2019 "Smart Toilet Energy and Water Efficiency Limit Values and Grades "[2].

At present, when detecting the heating function of the seat in the standard of smart toilet at home and abroad, it is necessary to locate 6 to 30 temperature measuring points on the surface of the seat. For seats with different shapes and sizes, manual drawing line positioning is time-consuming and labor-intensive, and the accuracy is not high. When testing the life of smart toilet, there are different kinds of smart toilet. The control methods include buttons, touch screen, etc. the trigger directions are different. The trigger on the horizontal plane and the trigger in the vertical direction require more stations and larger area. The fixed cleaning power detection tool has poor applicability. When the water temperature stability test is performed, the time-temperature curve collection frequency is not high. The existing equipment comprehensive detection device proves unsatisfying on integration, intelligence, time and effort cost, and precision [3].

Based on the above problems, this paper designs an integrated detection platform for smart toilet, which uses machine vision technology to locate quickly and efficiently, uses six-degree-of-freedom manipulator to detect all-round life of products, uses high-speed acquisition card to collect cleaning
force value, a multi-compatible mechanical tooling is designed for clamping different forms of products. The equipment has high precision, wide standard coverage and good stability. It is suitable for comparison and research of various detection methods. With the help of new equipment, it explores better quality detection and evaluation methods, which continuously improves the detection ability and fills the blank of intelligent equipment in the field of smart toilet detection.

2. Design and implementation
This device uses an integrated machine as the host computer to realize the collection and analysis of key data; the manipulator system is used to realize the clamping and positioning of the relevant performance fixtures; the vision system provides coordinate positioning for the manipulator; the Siemens PLC is used as the lower machine to control multiple temperature water tanks, frequency converters and pipe valves, as well as to collect and transmit temperature and cleaning force data. Figure 1 shows the design of the system.

The device is mainly composed of two parts: the control unit and the water supply unit. The control unit completes the hardware control, data processing and human-computer interaction of the whole system, including the integrated machine, the PLC, manipulator and the visual control system. The visual system provides position data through RJ45. By PLC, the water supply unit realizes constant temperature and constant pressure water supply and field data acquisition.

Figure 1. Schematic diagram of system hardware design

2.1 control unit
The integrated machine is used as the upper computer of the whole system, which is connected with
Siemens S7-200smartPLC、vision system, Turing robot controller and temperature checker JK-32U. Among them, Siemens S7-200smartPLC externally connects analog quantity acquisition module, analog quantity output module, thermocouple module, Turing robot controller, and so on.

Siemens AE08 analog data acquisition module and AT04 temperature thermocouple module respectively realize the acquisition of the toilet water supply water pressure, outlet water temperature, air temperature and wind speed, flow rate, cleaning force and cold and hot water supply pipe temperature and other key data. Siemens AQ04 analog output module realizes the frequency conversion control of water supply water pressure. Temperature checker JK-32U is used to realize the data collection of the temperature points of the toilet seat; the six-axis manipulator grips the fixture for the performance test. The coms camera obtains the position of each temperature measurement point of the toilet seat. The coms camera and the six-axis manipulator combine to accurately and efficiently draw the position of each temperature measurement point.

2.2 the water supply unit
The water supply unit is mainly composed of multiple water tanks with different temperatures, water pumps, supporting frequency converters, heating pipes, refrigerators, pressure stabilizer tanks, various on-site data acquisition sensors, pipelines and solenoid valves. The structure diagram of the water supply unit is shown in Figure 3.
This paper designed a comprehensive performance testing project that meets multiple standards such as GB 38448-2019 "Smart toilet energy efficiency and water efficiency limit value and grade", GB/T 34549-2017 "Smart toilet for sanitary ware", GB/T 23131-2019 "Electric toilet seat for household and similar purposes", CMBF 15-2019 "Smart toilet" and so on. All the water supply system is collected by PLC through real-time water pressure and pipe temperature, the pump is controlled by frequency converter, combined with solenoid valve, the constant pressure water supply is realized by steady pressure tank; As the standard requires multiple temperature points for the inlet water temperature, in order to ensure the stability of the inlet water temperature, this device uses a multi-temperature loop pipeline. At the beginning of the performance test, the solenoid valve is controlled to open and the inlet pipeline The water and the water tank circulate in real time. When the test conditions are reached, the circulating solenoid valve is closed to realize the water circulation in the pipeline and the water tank, and realize constant temperature water supply. The temperature stability of the whole water supply system is ±0.5℃and the pressure stability is ±0.005 MPa, which improves the stability obviously.

3. Seat ring detection system based on machine vision
The seat ring temperature measurement control system of this device is composed of a vision system and a 6-axis manipulator. The vision system is composed of a CCD camera, a light source, a vision controller, and a display. The physical map is shown in Figures 4 and 5.
This vision system adopts advanced series of CA series cameras with dense resolution layout, and has two data interfaces: network port and U port; VB2200 vision controller is a central processing device for integrated control and data processing of machine vision. The vision system has visual interfaces such as network port, USB3.0, light source interface, IO interface and so on. At the same time, it provides rich API interface function library to realize diversified control. The manipulator is connected to the vision controller through the Ethernet TCP protocol. After the controller receives the position coordinates fed back by the vision system, it accurately locates the corresponding point on the toilet seat through internal calculations. The structure diagram of the system is shown in Fig. 6.

Machine vision is a visual function system that replaces human eye with machine vision products, which consists of light source, camera, vision controller and so on[4]. The camera takes and generates video images and transmits them to the camera image acquisition device in real time. The image acquisition device converts the received video image signal into a digital image signal which is easy to
process by computer and sends it to the visual controller. The controller (image scaling, filtering, enhancement, edge extraction) processes the output results after the operation, at the same time guides the manipulator to accurately locate a certain point in three-dimensional space for the operation [5].

The manipulator communicates with the visual controller by modbus tcp protocol and is effectively connected by configuring the IP address, the specific settings are as follows: the manipulator teach pendant finds the "wired" control button and sets it. The camera captured pictures are processed by visual controller algorithm to obtain the accurate coordinates of all temperature measuring points in three-dimensional space, and feedback to the manipulator controller. The manipulator receives the coordinate signal of the space position and runs to the coordinate point in turn. According to the same way above, the manipulator completes the drawing of multiple temperature measuring points.

4. Experimental analysis
The stability and efficiency of the whole device are verified by testing the stability of sitting temperature and effluent temperature of several smart toilet devices on the market.

Table 1 single-point sitting temperature detection

| Sitting temperature | First | Second | Third  |
|---------------------|-------|--------|--------|
| sample 1            | 38.85℃ | 38.83℃ | 38.85℃ |
| sample 2            | 36.11℃ | 36.23℃ | 36.17℃ |

Table 2 Effluent temperature detection (5℃ influent, water potential)

| Water temperature       | First / Real-time influent temperature | Second / Real-time influent temperature | Third/ Real-time influent temperature |
|-------------------------|----------------------------------------|----------------------------------------|-------------------------------------|
| sample 1                | 37.33℃/5.2℃                           | 37.38℃/5.6℃                           | 37.16℃/5.3℃                        |
| sample 2                | 35.56℃/4.7℃                           | 35.72℃/5.1℃                           | 35.94℃/5.2℃                        |

Table 3 Test time for 26 sitting temperature points

| Manipulator positioning detection time-consuming/ Manual location detection time-consuming | First         | Second         | Third          |
|----------------------------------------------------------------------------------------|---------------|---------------|----------------|
| sample 1                                      | 6min+10s/15min+3s | 6min+15s/15min+6s | 6min+8s/15min+11s |
| sample 2                                      | 6min+35s/15min+10s | 6min+35s/15min+8s | 6min+35s/15min+13s |

It can be seen from Table 1 that the temperature fluctuation of the single-point sitting temperature detection is within ±0.5℃; Table 2 shows that when the inlet water temperature meets the standard, the water temperature fluctuation is within ±0.5℃; From Table 3, it can be seen that the manipulator greatly shortens the time for sitting temperature detection. Tests show that the detection accuracy, efficiency, and integration of this device have been significantly improved.

5 Conclusion
The smart toilet is a product of interdisciplinary integration with various performances. The integrated performance testing device of the smart toilet based on the industrial computer designed in this paper improves the temperature and water pressure stability of the device through the redesigned pipeline. At the same time, combining machine vision and manipulators, a set of automatic sitting temperature positioning system is designed, and a CCD camera is introduced innovatively to realize the detection of the sitting temperature of the smart toilet and improve its position accuracy. The experimental results show that the detection accuracy, efficiency, and integration of the device have been
significantly improved, which solves the detection of multiple comprehensive performances of the smart toilet, and has high application value.

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