Recognition of Piano Play Gesture Based on Infrared Sensor Detection Rod

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Abstract. Piano playing gloves are a new intelligent wearable device. The multi-inertial sensors in the gloves can sense and analyze the gesture state of piano players in real time, which can make piano learners know whether the playing gestures are standard in real time, thus effectively improving piano learning efficiency and interest, and reducing learning costs. Different from gestures in other application fields, piano playing gestures have the characteristics of diversity, rapidity, great dynamics and strong time-varying. A design scheme of non-contact gesture recognition system is proposed. In this system, infrared and ambient light sensors Si1143 are combined with capacitive touch-sensitive microcontrollers such as C8051F700 and C8051F800 to realize non-contact gesture recognition, which can be used for various actions and gesture detection and distance calibration of target objects.

Keywords: infrared sensor · Play the piano · Gesture recognition

1 Introduction

Piano education is a teaching activity with strong professionalism and long learning cycle. Traditional piano teaching is based on one-to-one teaching between teachers and students, which has high time and economic cost. Through wearable sensors, students can collect and identify the playing data of their hands, and can practice independently. By analyzing the training data, teachers can have a comprehensive grasp of students' practice and give feedback to students. Gesture recognition mainly includes visual recognition and data gloves. In vision-based gesture recognition, users generally don't need to wear acquisition equipment, but they are easily affected by environmental factors such as light blocking and camera placement. In contrast, the recognition technology based on data gloves can get more reliable hand movement data through physical interaction with users, and the recognition accuracy is relatively high [1].

The development of human-computer interaction technology has greatly enhanced the intelligent design of application systems, and gesture recognition has gradually become the core technology of human-computer interaction. With the development of man-machine interface technology and design concept, infrared proximity sensor is gradually becoming the innovation point of non-contact gesture recognition user interface. The early traditional infrared proximity sensing system consists of old photoelectric

C. F. Peng et al. (Eds.): EIMT 2023, AHSSEH 8, pp. 378–385, 2023.
https://doi.org/10.2991/978-94-6463-192-0_49

detectors and photoelectric circuit breakers, and its triggering mode is based on whether it moves or interrupts. However, these devices are limited in application by sensor size, power consumption and configurability. Compared with these early infrared proximity sensors, Si1143 sensor of Silicon Labs is not only smaller in size and lower in power consumption, but also can drive multiple infrared LEDs, which can realize advanced multi-dimensional gesture input function [2].

2 Framework of Piano Playing Gesture Recognition System

The framework of dynamic gesture recognition system is shown in Fig. 1. The general goal of gesture recognition module is not only gesture recognition, but also the modeling of different gestures. Finally, the HMM gesture model trained by a large amount of gesture distance information must be universal, that is, it can recognize the same gesture in the untrained set. Therefore, in the process of data preparation, it is necessary to collect 20 groups of gesture data as test data, and each group of data is a gesture [3]. At the same time, the distance information of each gesture is collected for 50 consecutive times for HMM model training. Because HMM is a probability evaluation model based on statistics, the preprocessing of gesture data is very important in the training process, and every step will affect the universality of the final model establishment and the accuracy of recognition. In this paper, the preprocessing of dynamic gesture distance information focuses on gesture endpoint detection and gesture segmentation. At the same time, the selection of hidden states and the optimization of parameters of HMM model are directly related to the cost of model training and the efficiency of final recognition [4].

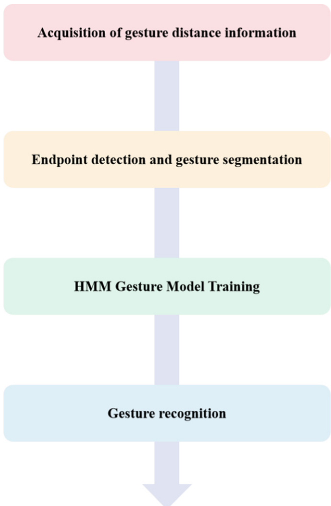

Fig. 1. Dynamic gesture recognition system framework

3 Infrared Technology to Realize Gesture Sensing

Si1143 proximity ambient light sensor is suitable for contactless gesture sensing. Si1143 can provide up to three LED drivers, and can sense gestures in 715cm product interaction area. We use infrared technology to realize motion sensing, mainly using position-based and phase-based gesture sensing.

(1) Gesture sensing based on position realizes gesture sensing by calculating the position of the object.
(2) Gesture detection based on phase can judge the moving direction of the object through the change of timing signal.

3.1 Comparison of Advantages and Disadvantages of the Two Methods

The advantage of the position-based method is that it can provide the position information of the target and allow the system to achieve proportional control. The main disadvantage of location-based method is the accuracy of location calculation. The location algorithm assumes that the LED output is spherical, but in practical application, the LED output is conical [5]. This method also assumes that the whole output of LED is uniform light intensity, but in reality, the light intensity will be attenuated. Moreover, this method does not consider the shape of the target, and a unique shape of the object will lead to inconsistent position output. For example, the system can't distinguish the difference between the hand and the wrist, so the detection of the area related to the wrist movement is less accurate. The location information provided by this method is sufficient for low-resolution systems, but the current location algorithm is not suitable for fixed-point applications. For applications that don't need position information, the phase-based method provides a very reliable method to detect gestures. Each gesture can be detected at any entrance or exit of the detectable area. The disadvantage of this method is that it cannot provide location information. This means that the number of gestures that can be realized is more limited than the location-based method. Phase method can only distinguish the direction of entry and exit from the detection area, but can't detect any movement in the detectable area [6], the advantages and disadvantages of the two methods are shown in Table 1.

3.2 Combining the Two Methods to Improve Gesture Recognition

The system combines the two methods to make up for each other's defects. The position-based method can provide some position information for proportional control, and the phase-based method can be used to detect most gestures. The combination of these two methods can provide a powerful solution for gesture sensing [7].

Characteristics based on spatial characteristics: In the process of piano playing, the posture angles between the upper and lower joints of the fingers and between the fingers and the back of the hand will be quite different, so the information of the fingers and the back of the hand at the key pressing moment is extracted. The extracted spatial characteristics are shown in Table 1 (i, j represent the number of inertial devices, as shown in Table 2).

Table 1. Comparison of the advantages and disadvantages of the two methods

Location-based approach	**merit**	**weakness**
	Provides the location information of the target	Accuracy of the position calculations
	Allows the system to implement proportional control	The LED is assumed to be a spherical output, but in practice the output of the LED is conical
		The entire output of the LED is assumed to be uniform light intensity, but the light intensity decreases in practice
		Regardless of the shape of the object, an object with a unique shape causes an inconsistent positional output
Phase-based approach	Very reliable way to detect hand gestures	Location information cannot be provided
	Each gesture can be detected at any entrance or exit of the detectable area	The number of gestures is more limited than the location-based methods
		Only the entry and exit directions can be distinguished from the detected area, and any movement in the detectable area cannot be detected

Table 2. Characteristics based on spatial characteristics

Feature description	**Feature definition**
Flexibility of upper and lower joints of fingers	Pitchi-Pitchi-1 (i = 4,6,8,10)
Flexibility between fingers and the back of hand	Pitchj-Pitch1 (j = 2,4,6,8,10)

Coupling characteristics between fingers: During piano playing, different playing gestures lead to different relative information between fingers. Information such as the relative attitude angle, relative acceleration and angular velocity between adjacent fingers will change. The extracted coupling characteristics between fingers are shown in Table 3.

Table 3. Coupling characteristics between fingers

Feature description	Feature definition
X-axis relative acceleration of adjacent fingers	axi-axi-2(i = 4,…,10)
Y-axis relative acceleration of adjacent fingers	ayi-ayi-2(i = 4,…,10)
X-axis relative angular velocity of adjacent fingers	gxi-gxi-2(i = 4,…,10)
Relative angular velocity of Y axis of adjacent fingers	gyi-gyi-2(i = 4,…,10)
Relative curvature of adjacent fingers	Pitchi-Pitchi-2(i = 4,…,10)

4 System Hardware and Software Design Related

4.1 Proximity Sensing

Si1143 can drive three separate infrared LEDs. When these three infrared LEDs are placed in the L-shaped configuration, the objects in the three-dimensional adjacent field can be triangulated. Every time the PS is measured, Si1143 will make up to three measurements, depending on the parameters enabled in CHLIST. You can also modify these measured ADC parameters to allow normal operation under different ambient light conditions. In these three measurements, the LED selection can be set. By default, one LED driver is turned on for each measurement, but it is easy to reverse the measurement order or turn on all LEDs at the same time. According to the situation, the measured value of each approach can be compared with the threshold set by the host [8].

In order to dynamically support different power efficiency situations, each output infrared LED current can be set independently, and can take any value from several milliamps to several hundred milliamps, so the host can dynamically approach the detection performance or optimize energy saving. This function allows the host to reduce the LED current after an object has entered the proximity range, and can still track the object when the lower current setting is adopted. Finally, through flexible current setting, the controlled current sink is used to control the infrared LED current, thus improving the accuracy.

4.2 Ambient Light

Si11413 has a photodiode that can measure visible light and infrared light at the same time, but the visible light photodiode is also affected by infrared light. When measuring illuminance, the same spectral response as that of human eyes is required. If the illuminance needs to be measured accurately, the extra IR response of visible light photodiode must be compensated. In order for the main controller to correct the influence of infrared light, Si1143 reports the measurement results of infrared light in a separate channel. Separate visible light photodiode and IR photodiode are suitable for various algorithm solutions. The main controller can perform two measurements, and run the algorithm to deduce the illumination equivalent to human eyes. Running the IR correction algorithm in the host computer can flexibly adjust the system-related variables. If the visible light blocked by the glass used in the system exceeds the infrared light, the

IR correction needs to be adjusted. If the host has not made any infrared correction, you can turn off the infrared measurement in the CHLIST parameter [9].

4.3 Main Controller Interface

The main controller INTerface of si143 consists of SCL, SDA and INT pins. The purpose of designing int, SCL and SDA pins is to enable si143 to enter the shutdown mode through software commands without interfering with the normal operation of other I2C devices on the bus. The I2C slave address of Si1143 is 0x5A, which can respond to the global address (0x00) and the global reset command (0x06), but only supports 7-bit I2C addresses, not 10-bit I2C addresses [10].

4.4 Operation Mode

The operation modes of Si1143 include shutdown mode, initialization mode, standby mode, forced conversion mode and spontaneous mode, and it can be in one of many operation modes at any time. And the operation mode must be considered, because this mode has an impact on the overall power consumption of Si1143.

4.5 Command and Response Structure

The internal sequencer is not awakened when reading or writing to all I2C registers of Si1143 (except for writing to the COMMAND register). Si1143 can be operated in forced measurement mode or spontaneous mode. In the forced measurement mode, unless the main controller explicitly requests the Si1143 to perform measurement through a specific command, the Si1143 will not perform any measurement. At this time, the CHLIST parameter needs to be written to let Si1143 know which measurements to make. Similarly, when the ALS counter expires, a maximum of three measurements (ALS_VIS, ALS_IR, and AUX) are performed according to the measurements enabled by the high bit of the CHLIST parameter [11–15].

5 Conclusion

In many gestural environments, it is necessary to use the unknown contact when the user's hand shakes, sweats or holds objects that are not suitable for touch screen operation.The gesture recognition system of Si114x series sensors can meet the requirements of non-contact. For a large complex and efficient gesture recognition system, the required recognition range and precision are high, so it is not suitable for the simple system implementation in this paper. But for simple gesture recognition applications that users need, the system described in this paper can basically be realized. In this system, infrared and ambient light sensors Si1143 are combined with capacitive touch-sensitive microcontrollers such as C8051F700 and C8051F800 to realize non-contact gesture recognition, which can be used for various actions and gesture detection and distance calibration of target objects. On the premise of low cost and low difficulty, it can meet the needs of users and enrich the functions of the controller.

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