Screen-Camera Communication System Based on Dynamic QR Code

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Abstract. Screen-camera communication is a new information communication method based on visible light. However, such communication mechanism relies on barcodes to transmit information which suffers a limited capacity and a low communication rate. Hence, we proposed a color multiplexed dynamic QR Code communication system based on mobile devices. Use this method can further improve the communication rates over the system. In our system, a self-defined frame structure has been designed for a better reliability and diversity in the transmission. The experiment results indicated that in the traditional dynamic QR Code transmission mechanism, the real-time communication rate is 150 Kbit/s and the non-real-time communication rate is 300 Kbit/s. While, under the proposed color multiplexed dynamic QR Code communication system, the real-time communication rate can reach 320 Kbit/s and the non-real-time communication rate can reach 900 Kbit/s. After multiple experimental tests, it can transfer text, picture and audio files with no error.

Keywords: Screen-camera communication; Dynamic code; Color code; Custom frame structure.

1. Introduction

At present, the common communication methods of mobile devices are WiFi, Bluetooth and cellular network, which can provide reliable services when the signal or connection is stable and available. However, these three communication methods all have these different disadvantages. For example, WIFI and cellular mobile networks do not exist everywhere, Bluetooth needs to match the link in advance. In order to make up for the shortcomings of these three methods, a new communication method is proposed—screen-camera communication [1]-[3]. Screen-camera communication is a kind of visible light communication, which uses the camera to scan and identify the screen display information for data exchange. With the development of the LCD screen at the sending end and the improvement of the pixels of the mobile phone camera, the screen communication through the camera has been paid more and more attention[4][5]. At present, the most commonly used way is to scan the QR Code for information transmission. Store the content in the QR Code and open the unified resource locator (URL) after scanning to get the content in the QR Code. However, the capacity of QR Code sheet is limited, so it is unable to store content with a large amount of information. Therefore, there have been a lot of studies on expanding the capacity of bar codes [6]-[8].

In 2016, Nanyang Technological University Singapore proposed the use of color-multiplexed QR Codes for mobile communication, which can expand the capacity of individual QR Codes. Due to the limited capacity of traditional dynamic QR Code, the storage capacity can be further expanded by multiplexing primary tone and secondary colors [9].

In this paper, through the use of multiple QR videos, the transmitted content is stored in the dynamic QR Code video stream, and the receiving end uses an Android mobile phone with a camera to shoot and...
scan, split the video into a single QR Code, and then recover and integrate the content to obtain the transmitted content. By multiplexing three pieces of QR Code, the color QR Code can be generated and the dynamic video can be generated to send the file. The time of displaying the video in this way will be greatly shortened, the transmission rate of the QR Code can be improved, so the feeling of use can be improved and reduce waiting time. After the received video is decomposed into pictures, the color channel of the color QR Code is separated to recover the original data.

2. Traditional Dynamic QR Code

2.1. Custom Frame Structure

In order to meet the transmission of different types of information carried by the system and facilitate the subsequent information processing during reception, the frame structure is designed as shown in Table 1.

| Table 1. Custom frame structure corresponding table. |
|---------------------------------------------------|
| Frame header | Data frame | Frame trailer |
| Sync. Type | Data Flag | Data Length | Flag Bit |
| Denary | Denary | Denary | Denary |
| 10 | 101 | 500 | 101011 |

Through the design of the frame structure, we can realize the functions of information classification, recognition and matching, information recovery and so on. The bit stream information corresponding to the transmission content is read, and the bit stream is split according to the data block and encapsulated into frames. The frame structure is divided into three parts: frame header, data frame and frame trailer. The split bit stream information to be sent is encapsulated. The frame header part of the encapsulated first frame includes the synchronization bit, the type flag bit and the data length bit; the data frame part is the data bit represented by the binary number; and the tail part of the frame is the flag bit represented by the decimal number. For frames other than the first frame, the frame header portion contains only synchronization bits and data length bits; the data portion and frame trailer portion are the same as the first frame. Among them, the synchronous bit is used as "1, 2, 3, …n" marked by an increasing decimal number; the data length bit is represented by using a decimal number to represent the binary stream length of the data bit of the frame. The frame trailer marks the end of a frame with the same incremented decimal number as the synchronization bit. Data bits store binary bit streams such as "101011001…", the data type tag bit uses "001, 002, …" marked by three incremental decimal numbers, and the different formats of the information carried are distinguished by certain corresponding rules. The corresponding rules are shown in Table 2.

| Table 2. Partial data type corresponding format. |
|------------------------------------------------|
| Data Type | File Format |
| 001 | txt |
| 002 | doc |
| 003 | docx |
| 004 | xls |
| 101 | bmp |
| 102 | jpg |
| 103 | png |
| 104 | gif |

According to Table 2, it can be seen that when the received data type flag bit is "102", the data type representing this transmission is jpg. According to the flag bits of the data type contained in the decoded, the receiving unit can judge and generate the file with the corresponding format and store the parsed information. Judge the integrity of the information according to the data length bits to avoid errors caused by data loss and prepare for follow-up processing. The synchronization bit is used to determine
that the frame data captured by the receiving unit is located in the position of the whole video stream, which is convenient for subsequent judgment of its integrity and removal of repetitive processing.

2.2. The Generation of Traditional Dynamic QR Code

According to the storage capacity of the QR Code, the information stream containing the frame header, the data frame and the end of the frame is grouped. Each group of bitstream information corresponds to a piece of QR Code information content. Generate multiple QR Codes according to the QR Code generation rules. The steps for generating QR are as follows:

(1) Data analysis to determine the data type. Choose error correction level, four levels of LMQH.
(2) Data coding: data coding is carried out according to the corresponding relationship of QR Codes.
(3) Error correction coding: there are 40 levels of two-dimensional code. According to the two-dimensional code level and error correction level, the error correction codeword is generated, and the error correction codeword is added to the data codeword sequence to form a new sequence.
(4) Construct the final data information: under the condition that the specification is determined, put the sequence generated above into blocks in order.
(5) According to the QR Code structure, the QR Code is generated, and the QR Code structure is shown in the figure 1(a).
(6) Add mask and version information. The result of mask addition is shown figure 1(b).

![Figure 1. (a) The structure of QR Code; (b) Result image of adding mask.](image)

According to the above generation process, a plurality of QR Code pictures are generated, and the generated QR Code pictures are sorted to synthesize the video.

2.3. Traditional Dynamic QR Code Analysis

In order to improve the universality of visible light screen, two modes of real-time analysis and non-real-time analysis are proposed in this paper. In the process of video parsing, if the video display speed is too fast, it will cause multiple frames to overlap, resulting in the inability to accurately identify the QR Code content of each frame. In order to avoid inter-frame mixing, the frame rates of the display screen and the receiving camera need to meet the Nyquist theorem: \( f_r \geq 2f_s \). According to the formula, \( f_r \) is frame rate of scanning, \( f_s \) is display screen sending rate. Because the screen communication is a one-way transmission, there is no feedback mechanism, so it is impossible to judge the correctness of the received information. When the transmission frame rate is high, in order to ensure the stability of the system, the cache mechanism is introduced. The cache mechanism can solve the problem that the data of the previous frame has not been processed and the data of the next frame has been transmitted to the receiving unit, resulting in the loss of data. This paper chooses Linked Blocking Queue as the cache scheme. The queue adopts the principle of first-in, first-out. The video captured by the camera is unframed, and each frame image is sent to the buffer area according to the receiving order, and extracted in the receiving unit according to the image order. The linked list can flexibly open up the cache space to ensure that the cache technology can still be used when the receiving unit runs out of
space due to continuous memory. In the case of non-real-time analysis, the scheme is adopted to record the displayed video first and then analyze it. Non-real-time parsing adds a feedback loop to visible light screen-camera communication. When the number of frames that appear after the frame split is not equal to the data length bits of the first frame, it can be split again from the recorded content until the number of frames to be parsed is equal to the data length bits of the frame. The non-real-time resolution mechanism has little overhead on the receiving unit and is suitable for all devices.

3. Color Dynamic QR Code

The color reuse of the QR Code based on the traditional dynamic QR Code can effectively reduce the video playback time, reduce the waiting time, improve the sense of experience, and provide high-speed visible link communication. The schematic diagram of the transmission structure of color dynamic QR Code is shown in figure 2.

3.1. Color QR Code Generation

At the sending end, the generated QR Code is numbered, and the three QR Codes are reused as a group for color reuse. In order to avoid the decoding error caused by the similarity of color modules in the process of color QR Code recognition and analysis, it is necessary to have large difference and contrast in color selection. Replace the white of the three QR Codes with red, green and blue at one time according to the RBG color model space. When the three QR Codes overlap each other, they produce a secondary color. A new QR Code image consists of a mixture of all primary and secondary colors. After the color is mixed, the color QR Code has eight colors, and the capacity of it is three times of traditional QR Code, the schematic diagram of the effect is shown in the figure 3.

3.2. Analysis of Color Dynamic QR Code

In the shooting process, the screen performance, light intensity and shooting angle will cause the error of color recognition. Color restoration can effectively improve the accuracy, but it will greatly reduce the resolution rate. The reused 8 colors have great difference and contrast, and the QR Code itself has the function of error correction, which can reduce the bit error rate caused by color error. Therefore, the received color QR Code is processed by color separation directly. The stored information can be obtained by parsing the separated QR Code.
4. Experimental Results and Analysis
Two Huawei Mate9Pro phones and a DeLL computer are used as the experimental hardware platform, Eclipse, IntelliJ and Android Studio as the software platform, and the developed mobile application as the test platform. The relevant parameters of the mobile phone are shown in Table3.

| Indexes             | Parameters                      |
|---------------------|---------------------------------|
| Model               | Mate9Pro                        |
| Camera head pixel   | 12 million and 20 million pixels|
| Screen material     | AMOLED                          |
| Screen resolution   | 2560 pixels *1440 pixels        |
| Frame rate /Hz      | 60Hz                            |
| Preview fram /fps   | 30fps                           |

The experimental test environment is shown in figure 4. Under normal indoor light conditions, the test transmission distance is 30cm, and the receiving equipment is parallel to the angle of the real equipment. Send many different types of files to test the system.

At the receiving end, the received color QR Code is split into frames. Separate the color channel of the color QR Code of a single sheet, and the simulation results are shown in figure 5. Although the split bar code can not be completely restored to the original bar code, it does not affect its information recognition.

In this paper, experiments are carried out on files in various formats. Based on the custom frame structure, the experimental test can carry files of txt, word, xls, xlsx, bmp and MP3 types. In this paper, the transmission performance of traditional QR Code and color QR Code are tested respectively. At the size of barcode is 200*200 pixels, the amount of frame information is 10Kbit. When communicating in real-time, the frame of preview is 15 fps; when communicating in non-real-time, the frame of preview is 30 fps. The transmission rates of different dynamic barcodes are shown in the table4. Through the design of dynamic QR Code, different types of information can be stored and transmitted. Using the dynamic...
color QR Code, the transmission time is shortened. In order to improve the universality, this paper designs two transmission modes: real-time transmission and non-real-time transmission.

Table 4. Transmission rate of dynamic QR Code.

|                     | Traditional QR Code | Color QR Code |
|---------------------|---------------------|---------------|
| Real-time transmission rate | 150Kbit/s           | 320Kbit/s     |
| Non-real-time transmission rate | 300Kbit/s           | 900Kbit/s     |

5. Conclusion
In this paper, a new type of screen-camera communication is proposed, which can communicate between the screen and the camera by playing the QR Code video dynamically. Through the design of the frame structure, the accuracy and reliability of QR Code transmission are improved. When the acquisition speed and transmission speed satisfy the Nyquist theorem, the recognition error caused by inter-frame mixing can be avoided. Because the storage capacity of traditional QR Code is limited, the multiplexed color QR Code proposed in this paper can effectively solve this problem. Compared with the transmission mode of traditional dynamic QR Code, the real-time rate of color multiplexed QR Code is increased by 213%, and the non-real-time rate is increased by 300%. Through the experimental test, the dynamic QR Code screen-camera communication system designed in this paper can transmit many types of files, such as text, pictures and so on.

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