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A Smart Cyber-physical Alarm System and its Application for Assisted Living

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Abstract: Security issues are increasingly obvious. An automated real-time online alarm system to ensure the safety of property and personality while considering numerous smart Terminal Equipments (TE) becomes a major challenge. At the same time, this is representative of novel and emerging alarm system for assisted living in the daily life. Two problems of current alarm system are identified. A smart Cyber-Physical Alarm System (CPAS) based approach is proposed to address these problems. A prototype system installed in a house to assist living has been running stably and shows quite promising performance.

Key words: Cyber-physical system, TCP/IP connection, embedded image processing

INTRODUCTION

As a intelligent integration of calculation, network and physical entities, Cyber-Physical System (CPS) was first proposed by Lee (2008), Sha *et al*. (2009) and Stankovic *et al*. (2005). The cyber word and the physical word, interacting with each other, will be connected through sensors and actuators network and that formed the cyber-physical system which is also the network system with numerous embedded systems and physical objects. The CPS will further change the way of interaction between human and nature and it is recognized as the third wave of the world information industry followed by the Computer, Internet and Mobile Communication Network. Its application covers a wide range of fields that closely with the national economy (Shah *et al*., 2007), such as energy, transportation, security, medical and health care, etc.

The development of network communications and computing technology has provided technical support to achieve the design of intelligent security. Relevant research has made great progress. Li (2006a) proposed the way of wireless alarm based on ZigBee to address the issues that the traditional wired alarm faced, such as wiring difficulties, resource consumption. Li (2006b) discussed the way of using GPRS technology to achieve wireless remote alarm, solving the problem of the limited transmission distance of ZigBee (20-100 m) and Li (2009) brought forward the way of combination of ZigBee and GPRS alarm by using their respective advantages. As the case of no internet covered in the remote area, GSM-SMS based alarm method was proposed by Sun and Yu (2008) and Guo *et al.* (2010) put forward the idea of combination of GPRS and SMS based alarm mode, made up the deficiency of single alarm method based on GPRS or SMS. Li (2009) proposed a method that combining the infrared sensor with image monitoring and send the alarm image information to user's mobile-phone which improved the reliability of alarm. A redundant alarm mode based on two kinds of control networks (GPRS and PSTN) was proposed by Hu and Chen (2007), when one control network fails, it will switch to another control network to complete the alarm and it reduced the possibility of alarm communication failure. The research point above all of them is based on intrusion prevention and limited to infrared sensor only or image monitoring only, not a good combination of them. Although, Liu (2009) presented the combination of infrared sensors and image monitoring, its transmission way to complete the alarm is not in real-time, with a serious lag. These security alarm systems above take the safety of property as a starting point, but not take the safety of the increased aging people into consideration. Fleck and Strasser (2008) and Nam *et al.* (2008) proposed an intelligent monitoring system for assisted living (falling person detection), but purely based on human security while neglecting the security of property.

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Through above analysis, in fact, property security and human security are both belong to the large domain of assisted living system. In the view of the limited transmission rate of GPRS (about 171 kb sec^{-1} in theory, about 20-40 kb sec^{-1} in practical) (Guo *et al*., 2010), a smart Cyber-Physical Alarm System (CPAS) was developed in the study by combining ZigBee and 3 G wireless communication technologies and applied to assisted living system. The system combined the infrared sensors with image monitoring, analyzed and solved the situation of abnormal dropped between PC and remote intelligent TE. Moreover, in this study, the improved method of embedded compressed image data transmission was adopted which eased the pressure of huge raw image data transmission without affecting the quality of image showed.

MODEL OF CPAS FOR ASSISTED LIVING

System model: In the field of assisted living system, traditional embedded alarm systems are in single alarm-means and in single alarm-object which cannot address security threats in a satisfactory manner. For example, they are purely based on GPRS or SMS in alarm-means, purely user-oriented or monitoring center-oriented in alarm-object. Although, Hu and Chen (2007) proposed redundant alarm mode, including two control networks, GPRS and PSTN. And the switching power consumption between two networks is high which does not meet the trends of low power consumption of the intelligent TE. Therefore, this study conducts a dual alarm network model.

Figure 1 illustrates the architecture of CPAS. There are two parts in smart TE, front-end and back-end. The front-end, with the combination of infrared detection, image monitoring and ZigBee wireless modules, is mainly used to the snapshot of detected human and transmit the image data through ZigBee. A high-speed microprocessor is needed in the back-end, such as DSP28X series. The back-end, with the combination of ZigBee and WCDMA wireless modules, is mainly used to receive the image data from the front-end through ZigBee and process the embedded image data, then achieve remote wireless alarm through WCDMA.

System features: ZigBee works at 2.4 GAS. of the global generic, 900 MHZ of the bandwidth, 20-250 kb sec^{-1} of the transmission rate and its physical layer and MAC layer used the 802.15.4 standard. The other protocols of ZigBee are developed by the ZigBee Alliance. The front-end of smart TEN, with no direct interaction among each other, establish a star-structure network by taking ZigBee technology as the communication means. This has the advantage of low cost, easy to expand and manage and not involving the routing function.

The front-end is in a dormant state except for being awaked by the intruded person. It will quickly snap the intruded person and then transmit the image data to the

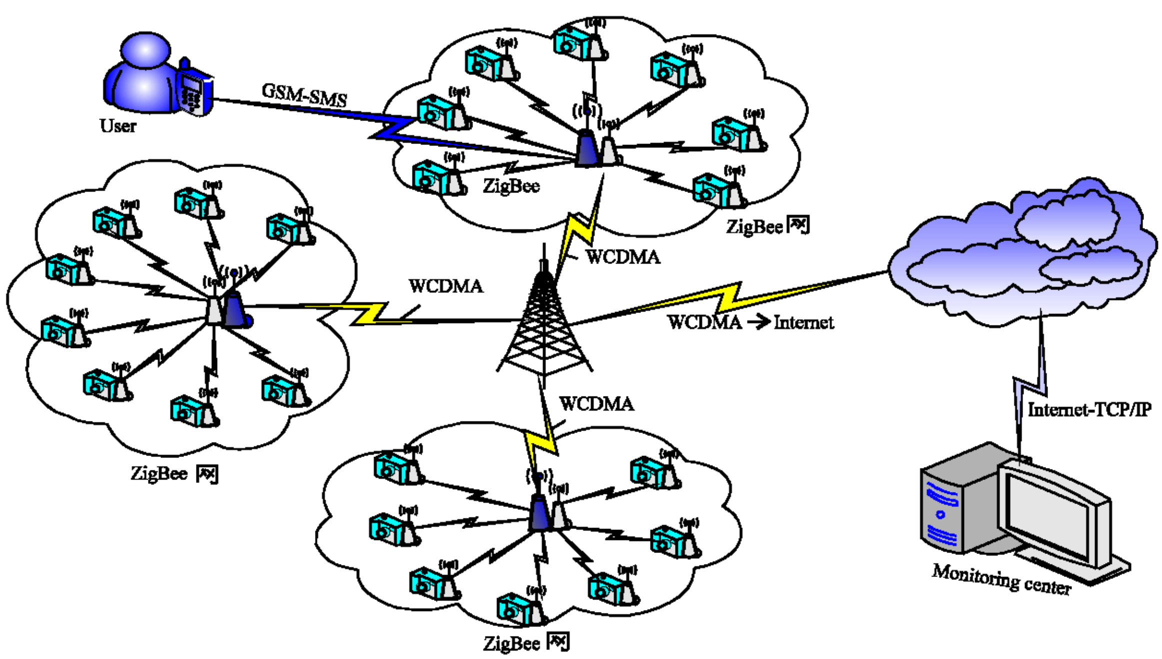

Fig. 1: Architecture of CPAS

back-end which helps to reduce the power consumption of the front-end. After processing the incoming data received through ZigBee network, the back-end will transmit the alert information to the security monitoring center through the means of WCDMA access to the internet on one hand. On the other hand, it will send the alert information to the user's mobile phone in the form of SMS. By doing this, the back-end realizes the conversion between ZigBee network and WCDMA network through high speed microprocessor which is easy to implement and avoids data loss in interconnection transmission. What's more, the two networks are independent without disturbing each other, showing quite good robustness. Figure 2 shows the process of network conversion.

In summary, the smart cyber-physical alarm system embodies the dual features. The alarm way includes both the way of SMS and TCP/IP. And the alarm objects not only for the users (individuals), but also for the security monitoring center (social). A nested structure is adopted for the alarm network, ZigBee network (Internal network) and WCDMA network (external network). And the conversion between the two networks through microprocessor shows high reliability and stability.

Problems to be solved: The distributed and automated smart camera (Tan *et al*., 2010) can analyze and identify the image independently. That brings the intelligence of

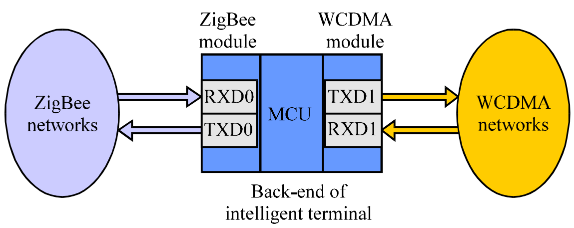

Fig. 2: Process of network conversion

single camera into full play, but ignored the advantages of smart swarm with not using the camera group. As is known to all, if there is no intelligence in a single object and assume "1" represent the function of a single object, then, 1+1 = 2. However, as for the single object with intelligence, then 1+1>2. Yilmaz *et al*. (2006), Hampapur *et al*. (2005) and Park and Trivedi (2008) shared the method of distributed management based on centralized host. Figure 3 shows its control structure. When hundreds of terminals continue to send alert information to the center, it is not easy to ensure the monitoring center in long-term stable operation. Moreover, it costs bandwidth. In summary, this kind of control method requires high quality for the control center. Therefore, the way to ease the communication load for the center is to be further resolved. In this study, based on the above consideration, the centralized-distributed combined control method is achieved by using the convenience of dual network. Figure 4 clearly indicated that the back-end is in centralized-mode relative to the front-end and in distributed-mode while relative to the monitoring center. It not only eases the communication load of the control center, but also helps to expansion.

It is the most important for the assisted living system to ensure the communication between the smart TE and the monitoring center reliably and in real-time. This cyber-physical alarm system just right addressed the two key problems that traditional remote alarm face. 1, when the remote monitoring center is power-off or crashed, the alarm TE (the back-end) whether can make a judgment in a timely manner 2, when the alarm TE (the back-end) drops in abnormal, the remote monitoring center whether can make a determination timely. As long as these two problems are resolved effectively, the reliability of alarm will improve greatly, because the failure of alarm is usually caused by the failure of communication.

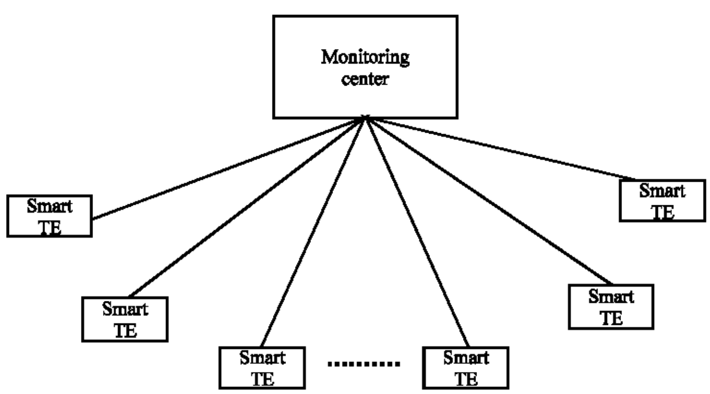

Fig. 3: Host centralized control architecture

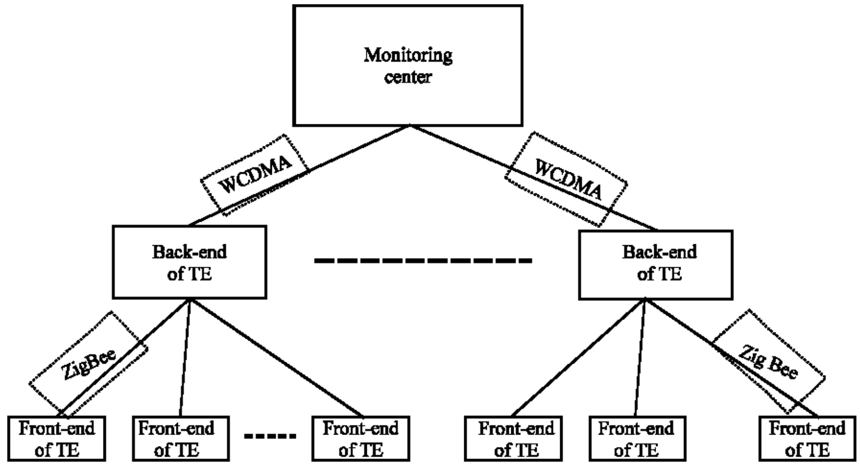

Fig. 4: Centralized-distributed combined control architecture

As for the problem of processing numerous image data in the alarm TE (the back-end), this study achieves the scheme of scalable layered coding transmission by adopting AC coefficients of the layered coding based on JPEG standard (Zhang and Liu, 2010). And it succeeds to ease the pressure of huge image data transmission without affecting the image quality. The second half of next section would focus on the idea of processing the layered embedded image data.

SYSTEM IMPLEMENTATION

Implementation of communication control: The most significant difference between cyber-physical alarm system and traditional embedded alarm system is mainly the way of the alarm communication control. In order to illustrate the differences better, the study takes the alarm system embedded in the car for an example. Suppose that one day, you stop your car beside a department store, as well as other cars and then go upstairs for a purchase. Suddenly, your car sounds an alert because of being hit by a bike (or other object) on the wheel or other body of your car. If you are not far away, you might hear the alert, but even if you hear it, you could not identify whose car is in alert sound (the first disadvantage of the traditional embedded alarm system). If you were far away, then you would not even know a car was in alarm (the second disadvantage). Of course, the pedestrian might pay an attention to the alarmed car. Perhaps your car is installed with more advanced embedded wireless alarm system and you would receive the alert information as soon as your car activates an alarm no matter how far you were (in the range of wireless distance). However, if the wireless signal is not good enough due to environmental factors, you might still not be able to gain the alert information from your car (the third disadvantage). Finally, when you go back to your car side, only to find your car scraped or hit lightly without knowing the offenders.

Through the above example, the disadvantages of the traditional embedded alarm system can be summarized as follows:

- Divergence of the alarm object which means that there is no specify object in the transmission of alert information
- Only one-way transmission of the alert information which means that the alarm TE can transmit information to the owner while the owner cannot take initiative to transmit information to the alarm TE

A reliable wireless communication is indispensable to achieve the binding of the alarm object and the two-way transmission of information. In this study, taking the WCDMA network (the 3rd generation mobile communication) as the wireless communication for the back-end is employed to solve the problem of transmitting large amount of image data. As the interactive communication between the back-end and the front-end is in short distance, the mature ZigBee technology is the preference. As many researches have been done in ZigBee, this study will not discuss it. The solution of TCP/IP transmission for the back-end by using WCDMA access to internet will be mainly explained in the following part.

Implementation of TCP/IP connection: A wireless communication module, embedded with TCP/IP protocol, is required for the TE to establish TCP/IP connection. To

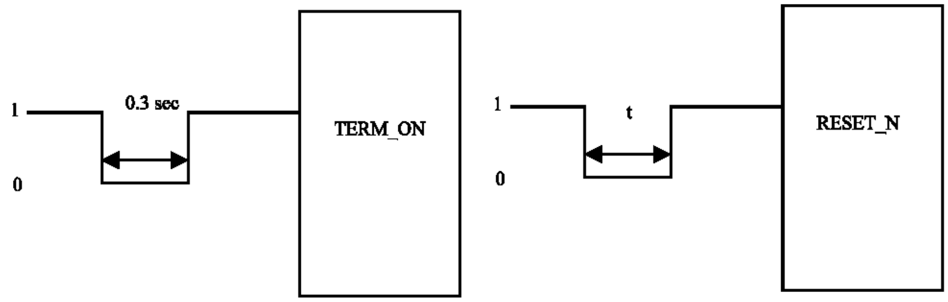

Fig. 5: Timing condition of MU103

ensure the long-term reliability of the connection between the alarm TE (the back-end) and the monitoring center, much experience and technology are required. There are two factors closely related to the reliability:

- **Hardware:** Timing condition of the module itself
- **Software:** As the indicator of the hardware is rigid, improve the function of software is the satisfactory way to solve the two major problems of the traditional embedded alarm system mentioned in section 2.3. Taking again MU103 (by Huawei) wireless module for instance, Fig. 5 illustrates its timing condition

The MU103 will be powered up when keep the TERM_ON in the state of low-pulled for more than 0.3 sec and will be powered off when keep the TERM_ON in low-pulled state for more than 2 sec. And if pull down the RESET_N for about t (50 msec<t<200 msec), you can reset the module. Making good use of the characteristics of the hardware can improve the function of software much better. Two cases should be considered to power up the module during software design. One is to boot the module normally, the other is to reboot the module in case of abnormal power-failure or system crashed. They are both boot-strap, but boot from different cases. In order to achieve the unity of the module boot process, this study views the case of module booted normally as the case of abnormal reboot. To this end, the boot process is not simply to pull down TERM_ON for more than 0.3 sec, but first to reset the module and then run the boot command. Repeated experiments show that the module can boot successfully both in the case of normal and abnormal.

After the wireless module is powered up, the microprocessor will control the module to connect TCP/IP through AT command. Figure 6 shows the process of TCP/IP connection (take IP: 210.32.161.189, port: 6800 for an example). Of course this is only the establishment of TCP/IP for smart TE, if to ensure the connection reliable and stable and self-recovery after be dropped, an intelligent software program is required.

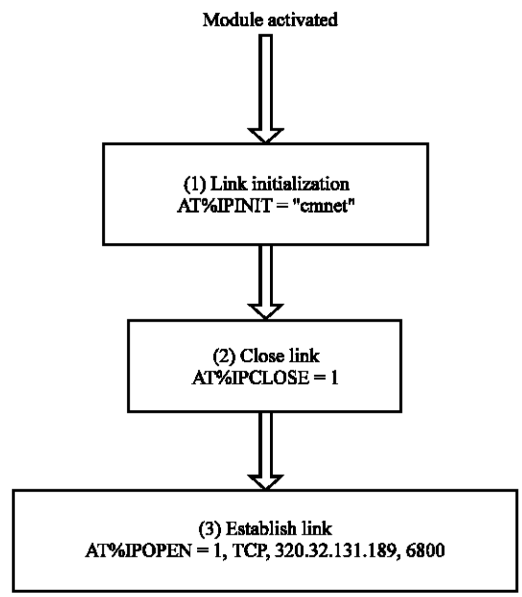

Fig. 6: Process of TCP/IP connection

Implementation of intelligent software: The intelligence of alarm TE (the back-end) is mainly reflected in the realization of the software program. Intelligence 1: when the remote monitoring center is powered-off, the alarm TE (the back-end) will make a judgment timely and can automatically re-establish TCP/IP connection as soon as the monitoring center is powered-on. Its implementation method is that the alarm TE (the back-end) will send an information packet to the remote monitoring center every minute during the time of the alarm condition being not occurred. If the transmission is failed, then set $n = n+1$ (n stands for the number of WCDMA sending failure). If $n>3$, this possibly shows that the network is jammed or the communication link is interrupt. Then, the smart TE will disconnect the TCP/IP automatically and re-connect it immediately. Besides, the wireless module will be rested and re-booted if the TCP/IP has not being established continually for more than 8 times ($m>8$) and then re-establishes the connection of TCP/IP and takes circulation action of them until the TCP/IP connection is established. According to repeated experiments, it can be identified that the remote monitoring center is recognized to be failed when the module has been restarted continually for more than 3 times without establishing the connection of TCP/IP. The process of smart design of TCP/IP connection is showed in Fig. 7.

Figure 7 explains that the smart TE will transmit an information package to the monitoring center every minute during the time of alert un-occurred. Therefore, it can be identified that (Intelligence 2) the smart TE is recognized to be in failure if the monitoring center has not received an information package for a certain time (about more than 3 min). By sending a package to the monitoring center every minute to solve the problem of traditional alarm system is easy to realize and manifests the intelligence of alarm TE.

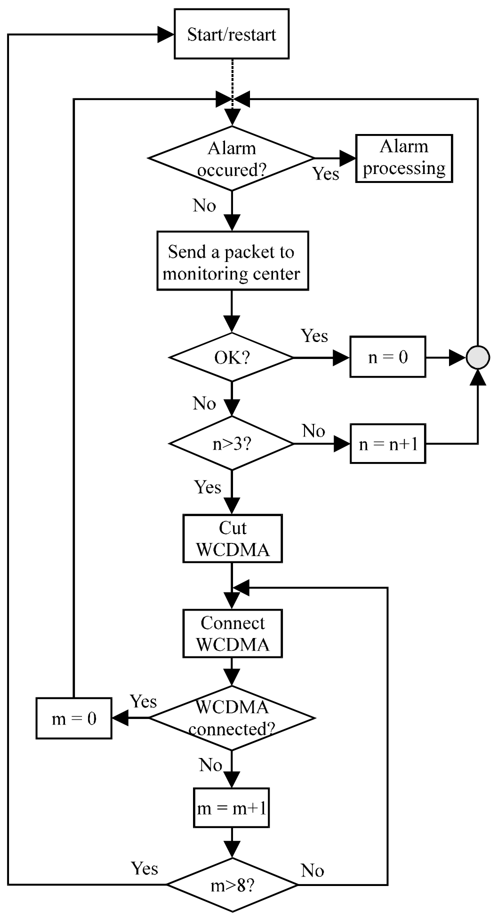

Fig. 7: Process of smart TCP/IP connection

Implementation of embedded image: In this study, the JPEG standard (Wallace, 1991) is adopted to process embedded compressed image. JPEG, shorted for Joint Picture Expert Group, is a compressed encoding standard for static picture formulated by ISO and CCIT. JPEG image compression is available in two formats, baseline sequential and progressive. The baseline format based on DCT stores the full resolution of the image in a single sequential top-to-bottom scan and it has been universally adopted. Figure 8 shows its coding flow. There are four operations included, color model transformation, Forward Discrete Cosine Transformation (FDCT), quantization and entropy encoder.

Color model transformation: The JPEG picture adopts the color model based on YC_rC_b which is more suitable for image compression compared to RGB model. As the human eye is far more sensitive to the brightness change Y than to the chromaticity change C of the image, the image compression can be achieved by part sampled without affecting the quality of image. Currently, there are two sample method universally adopted, YUV 411 and YUV 422 (YC_rC_b is derived from YUV) which represents the proportion of Y, C_b, C_r, respectively. Taking the YUV 411 sampling for instance, there are 4×3 = 12 bytes needed for 4 dots with RGB model while 4+2 = 6 bytes needed with YUV 411 model and the compression ration reaches to 50%. Equation 1 illustrates the conversion formula from R, G, B to Y, C_r, C_b:

$$\begin{aligned} Y &= 0.299\times R+0.587\times G+0.114\times B \\ C_b &= -0.1687\times R-0.3313\times G+0.5\times B+128 \\ C_r &= 0.5\times R-0.4187\times G-0.0813\times B+128 \end{aligned} \quad (1)$$

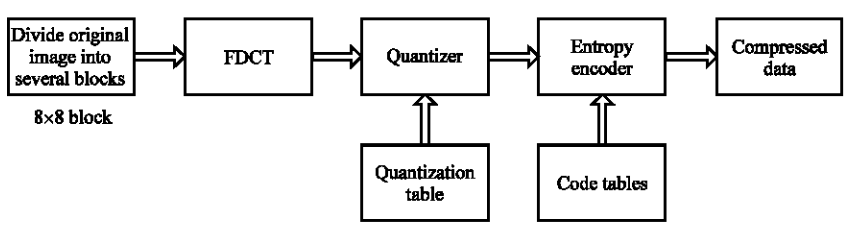

Fig. 8: Coding flow of the joint picture expert group

Then, divide the three components of image (Y, C_b, C_r) into 8×8 blocks. If the size of raw image data is not multiples of 8, then fill the rest with 0 to ensure the size is multiples of 8 first.

Forward discrete cosine transformation (FDCT): FDCT is widely adopted to transform spatial domain to the frequency domain in digital image processing, especially for image compression. Unlike the Fourier transformation that the parameter is plural, the FDCT reduced the processing operand in the data operation. When the signal is transformed to the frequency domain, the energy gathers in the area with low frequency. Equation 2 illustrates the two-dimensional FDCT formula (8×8 image blocks):

$$F(u,v)=\frac{1}{4}C(u)C(v)\left[\sum_{i=0}^{7}\sum_{j=0}^{7}f(i,j)\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16}\right] \tag{2}$$

where, C(u), C(v) are weighting coefficients:

$$C(u),C(v)=\frac{1}{\sqrt{2}}(u,v=0)$$
$$C(u),C(v)=1(u,v\neq 0)$$

The DCT coefficients are obtained through above transformation and view F(0, 0) as "DC" coefficient, all others as "AC" coefficients. The two-dimensional DCT can be decomposed into two times one-dimensional DCT to realize its operation. Equations 3, 4 illustrates its decomposed formula:

$$G(i,v)=\frac{1}{2}C(v)\left[\sum_{j=0}^{7}f(i,j)\cos\frac{(2j+1)v\pi}{16}\right] \tag{3}$$

$$F(u,v)=\frac{1}{2}C(u)\left[\sum_{i=0}^{7}f(i,v)\cos\frac{(2i+1)u\pi}{16}\right] \tag{4}$$

Quantization: After the DCT is achieved, the low-frequency component concentrates in corner of top left-hand while the high-frequency component distributes in the bottom right-hand. And the low-frequency component contained the main information of the image while the high-frequency one is not that important. Therefore, the high-frequency component can be neglected to reduce the image data quantity and realizes the goal of compression. In fact, quantification is required to remove the high-frequency component, in which the image information is lost. The quantification operation is described as follows: let the obtained DCT coefficient divided by a related value in the quantification table and round up the computed number and then a quantified result will be got. As the value of quantification table in the top left-hand is small while the bottom right-hand is large, this achieves to maintain the low-frequency component and suppress the high-frequency component. In order to guarantee that the low-frequency component first appears and the high-frequency component then followed, the quantified DCT coefficients need to rearrange to increase the number of continuously "0" in AC run-length encoding (RLE). And the method of "Z" glyph array is adopted, showed in Fig. 9.

Encoding: As the coefficient difference of two neighboring 8×8 blocks is very small, a Differential Predict Code Modulation (DPCM) is adopted for DC coefficient which can enhance the compression ratio. On the other hand, it is the difference of neighboring block's DC coefficient to be encoded $\Delta = DC(0, 0)_k - DC(0, 0)_{k-1}$. The rest 63 elements in 8×8 block, AC coefficient, are to be encoded with run-length encoding.

After obtaining the DC codeword and AC codeword, an entropy code is required to enhance the compression ratio further. In this study, the method of Huffman code is adopted which had been described in (Wallace, 1991).

Implementation of scalable layered coding transmission: The codeword stream produced by traditional sequential encoding does not have the function of layered transmission, so the AC coefficients are first supposed to be layered to realize the layered coding transmission. Seeing from Fig. 9, the coefficient in each oblique line is

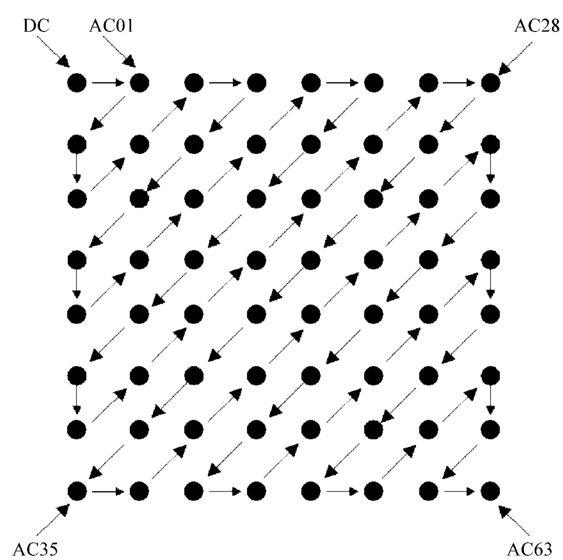

Fig. 9: Operation of "Z" glyph array

viewed as one layer and there are 15 layers in 8×8 block. The first coefficient, DC coefficient, is the L_0 layer. The oblique line corresponded to AC_1, AC_2 is the L_1 layer, the one corresponded to AC_3, AC_4 and AC_5 is the L_2 layer and the one corresponded to AC_{63} is the last layer. As the main image information has concentrated in the top left-hand corner, it's easy to retain the important layers to encode while neglecting the layers of no account and transmit the encoded data finally. In the decoding side, firstly, decodes the retained coefficient, then fills the rest vacancies with "0" and the scheme of layered compression transmission is achieved. In this way, alleviating the pressure of huge image data transmission for the smart TE can be easily done. And that may be the trend of the method for the embedded system to process image data.

AN APPLICATION CASE

According to the method of embedded image processing and the way of TCP/IP communication mentioned above, Fig. 10 gives the results of the experiment. The six images are original image, DC coefficient (L_0 layer), L_0+L_1, L_0+L_1, L_0+L_2, L_0+L_1+L_2+L_3 and L_0+L_1+L_2+L_3+L_4 based transmission, respectively.

Fig. 10(a-f): Comparison chart of different layered compression images (a) Original image, (b) DC coefficient (L_0 layer), (c) L_0+L_1, (d) L_0+L_1+L_2 (e) L_0+L_1+L_2+L_3 and (f) L_0+L_1+L_2+ L_3+L_4

Comparing the above five images to the original image, the Peak Signal Noise Ratio (PSNR) of DC only transmitted is about 28.16 dB and the value of PSNR would reach to 30.11 dB when L_0+L_1 transmitted. If transmitting L_0+L_1+L_2, the PSNR of the restored image can be bigger than 31.68dB and its value may reach to 32.83 dB if L_0+L_1+...+L_4, transmitted. Similarly, the PSNR will reach to 34.58 and 34.85 dB, respectively if L_0+L_1+...+L_7 and L_0+L_1+...+L_8 transmitted which shows that the value of PSNR is to be stable. Therefore, the coefficient behind the layer of L_8 can be neglected without affecting the quality of image. Of course, the value may be different for varies images.

CONCLUSION

This study represents a promising step towards the next generation of CPAS. The study first models the architecture of CPAS for assisted living, analyzes its key characteristics and proposes the problems to be solved that the traditional embedded alarm systems face. Then discusses the intelligence of communication control and the method of embedded image processing and succeeds to achieve them. A case is implemented which demonstrates quite satisfactory performance. Empirical results show that the system developed in this study is well suited for the assisted living, both of property safety and personal safety.

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REFERENCES

Fleck, S. and W. Strasser, 2008. Smart camera based monitoring system and its application to assisted living. Proce. IEEE, 96: 1698-1714.

Guo, Y.C., Y. Yu and C. Gao, 2010. Remote security monitoring system based on GSM/GPRS. Comput. Syst. Appl., 19: 123-126.

Hampapur, A., L. Brown, J. Connell, A. Ekin and N. Haas *et al*., 2005. Smart video surveillance: Exploring the concept of multiscale spatiotemporal tracking. IEEE Signal Process. Mag., 22: 38-51.

Hu, E.B. and Y.S. Chen, 2007. Strategy of reliable connection for people aerial defence alarm central-controlled system. Comput. Eng., 33: 250-255.

Lee, E.A., 2008. Cyber physical systems: Design challenges. Proceedings of the 11th IEEE International Symposium on Object Oriented Real-Time Distributed Computing, May 5-7, 2008, Orlando, FL., USA., pp: 363-369.

Li, J., 2006a. Research on infrared detection wireless alarm system based on ZigBee technology. Master Thesis, University of Electronic Science and Technology of China.

Li, S.X., 2006b. Wireless alarm system based on GPRS. Master Thesis, Wuhan University of Science and Technology, China.

Li, W., 2009. Design of remote monitoring and control system based on ZigBee and GPRS. Low Voltage Apparatus, 12: 37-40.

Liu, G.Z., 2009. Research on embedded alarm system based on GPRS. Sci. Technol. Inform., 25: 143-144.

Nam, M.Y., Z. Al-Sabbagh, J.E. Kim, M.K. Yoon, C.G. Lee and E.Y. Ha, 2008. A real-time ubiquitous system for assisted living: Combined scheduling of sensing and communication for real-time tracking. IEEE Trans. Comput., 57: 795-808.

Park, S. and M.M. Trivedi, 2008. Video Analysis of Vehicles and Persons for Surveillance. In: Intelligence and Security Informatics: Techniques and Applications, Chen, H. and C.C. Yang (Eds.). Springer, USA., pp: 407 424.

Sha, L., S. Gopalakrishnan, X. Liu and Q.X. Wang, 2009. Cyber-Physical System: A New Frontier. In: Machine Learning in Cyber Trust, Yu, P.S. and J.J.P. Tsai (Eds.). Springer, USA., pp: 3-13.

Shah, M., O. Javed and K. Shafique, 2007. Automated visual surveillance in realistic scenarios. IEEE Multimed., 14: 30-39.

Stankovic, J.A., I. Lee, A. Mok and R. Rajkumar, 2005. Opportunities and obligations for physical computing systems. IEEE Comput., 38: 23-31.

Sun, Q.W. and Z. Yu, 2008. An SMS alarm processing scheme in GSM. J. Fuzhou Univ., 36: 44-48.

Tan, J.X., X.F. Le and L.L. Zhang, 2010. Wireless measurement of electric parameters based on ZigBee. Telecommun. Elect. Power Syst., 1: 47-51.

Wallace, G.K., 1991. The JPEG still picture compression standard. Commun. ACM, 34: 18-34.

Yilmaz, A., O. Javed and M. Shah, 2006. Object tracking: A survey. ACM Comput. Surv., Vol. 38, No. 4. 10.1145/1177352.1177355

Zhang, Y.W. and Y.L. Liu, 2010. Research of static image compression algorithm based on JPEG standard. Electron. Des. Eng., 18: 78-80.