Water Motion Safety Recognition and Monitoring System Based on the Wireless Signal Transmission

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Abstract. Motion process monitoring is the core component of motion state analysis system and motion safety assurance system. For the water sport, implementation of monitoring is directly related to the safety and security of sportsmen, which is more significant. This paper presents a kind of underwater sports safety monitoring system based on radar idea. The system consists of four parts: video acquisition, image processing, data sample comparison and signal transmission. Reasonable cameras are used to capture the whole swimming pool, and then the motion information parameters of the swimmers are obtained by image segmentation and tracking, and compared with the standard drowning behavior parameters, so as to determine whether the swimmers are drowning or not. If it is judged that a person may be drowning, the system will send out a corresponding rescue signal, which will quickly alert and notify rescuers through the wireless signal transmission system, so as to rescue those who may be drowning, so as to enhance the safety of people's movement in the water. The drowning behavior is identified by the established drowning feature data sample set, which avoids the occurrence of invisible drowning events that are difficult to detect. By using the high-speed DSP, the data processing and alarm system's timely response can be realized, which greatly shortens the rescue time, directly improves the survival probability of drowning and reduces the physiological damage. The design of the monitoring system will eventually help the lifeguards to complete the task of underwater movement safety.

1. Introduction
According to statistics, about 370,000 people died of drowning in the world in 2012, and drowning ranked among the top three causes of unintentional injuries, and the vast majority of deaths were young people and children [1]. The drowning incident brought about the loss of life to the parties, the heavy damage to family, the legal disputes to the venues, and the permanent loss of human resources and wealth to the society [2]. Therefore, Margaret Chan (Director-General of the World Health Organization) pointed out that in recent decades, the World Health Organization has made unremitting efforts to reduce the drowning mortality rate of adolescents, and the awareness of prevention and rescue in this regard has been gradually raised from the state to relevant organizations. Good results have been achieved [3]. Even if you swim in a pool with safety monitors, the probability of drowning still exists and cannot be ignored. On the one hand, the pool is very densely populated, and it is difficult for lifesaving personnel to notice the behaviour of each swimmer; On the other hand, the
environment of the swimming pool is more complex, and the vision of the lifesaving personnel is easily blocked. The noise of the swimmers, the sound of the water, and other kinds of sounds are extremely noisy, resulting in a certain degree of influence on the senses of the lifesaving personnel; Again, whether the number of lifesaving personnel is sufficient and the ability of rescue personnel themselves to rescue is also affecting the timeliness of artificial rescue. After drowning, the time of hypoxia within 4 minutes is the golden time of rescue. At this time, the brain ischemia and hypoxia injury caused by drowning is mostly reversible. Four to eight minutes, if we can take effective and reasonable rescue, brain injury still has the possibility of recovery. Once drowning lasts more than 8 minutes, the brain tissue damage caused by drowning will be irreversible. Therefore, timely detection and rapid response to drowning are two crucial links in the process of drowning rescue. [4] How to improve the accurate identification of drowning events, promptly start the alarm mechanism and timely start effective rescue are the three effective measures, which are also the core content of this work.

Since the patent "swimming pool alarm recess" applied by Cortina in the United States in 1976 [5], to the world's first drowning alarm system "Neptune" produced by Vision IQ Company in 2001 [6], By the end of 2003, the drowning early warning system developed by the DEWS team of Nanyang University of Science and Technology of Singapore, which won the Chen Kah Kee Young People's Invention Award Open Group Winning Award [7], Overseas research on drowning alarm system has gone from conception, exploration and practice stage to practical and revision stage. Based on the previous research results, there are three main ways to realize the drowning alarm system:

(1) Realization of Sonar Monitoring System [8]. Sonar identification of a drowning person's body is basically based on the amount of air in his body. If the victim's lungs are full of water, the signal cannot be determined, or even no signal processing, thus missing the opportunity of alarm and rescue.

(2) Place the monitoring device on the sportsmen [9]. Some monitoring devices use microphone system to monitor the sound of heartbeat and breathing, and measure the interval between the occurrence and disappearance of these sounds, so as to determine whether drowning. Although this monitoring system has good effect, it has not been widely implemented because of the huge cost of installation, use and maintenance, high false alarm rate and great inconvenience to the athletes.

(3) Realization of Video Monitoring [10]. If the body sinks to such a depth, it is possible that the swimmer is in the final stage of drowning and there is not much time left for treatment accordingly. In addition, the installation of underwater cameras not only brings expensive installation and maintenance costs, but also faces such problems as cameras being blocked by swimmers' bodies or other objects, water quality turbidity and so on.

Based on the above problems, a full-space, full-time and Omani-directional underwater motion monitoring system based on the wireless transmission is proposed in this paper. First, the video collection system carries out the collection of the pool environment, captures the real-time activities of the pool personnel in the form of images, and communicates them to the computer host through the line. After the computer host receives real-time video information, the pre-installed monitoring software will perform real-time image processing and analysis, thus obtaining various kinds of motion parameters required by the human body. Then, by comparing the sample parameters of the data sample library, the drowning ability of each person in the pool was determined to identify whether anyone was drowning in need of rescue. After the software completed image processing and drowning analysis, the system obtained corresponding rescue signals. These signals were first transmitted by the host to the radio frequency transmission module of the wireless signal transmission system and sent by the launch module to the receiving module located in the pool. The alarm module is then transmitted to the corresponding area to generate alarm and rescue signals to complete the security monitoring function of the system.
2. Surveillance video collection

2.1. Parameters for surveillance cameras

The performance parameters of the monitoring camera include resolution, image sensor, main processor, image compression format standard, working temperature and humidity range, image transmission method, etc. These performance parameters have a direct impact on the monitoring video imaging.

The monitoring video collection site of this system is a swimming pool. Considering that the open environment of the swimming pool is generally daytime and there is a brighter light source even at night, the system does not need to use a high-sensitivity camera. The working light is generally 1–3 lekesi's ordinary photosensitive monitoring camera can meet the requirements. Taking into account the relatively high humidity of the pool environment, a camera with IP67 or above waterproof performance was selected. Since the system is a time-sensitive security alarm system, the system has high requirements for the speed of each link, so the monitoring camera using H.265 new video coding technology was selected. Under the same signal bandwidth, the camera using this encoding technology can obtain higher video transmission quality, and when transmitting video with the same resolution, the storage space and bandwidth can be greatly reduced, making the monitoring picture more smooth and stable. In addition to the various parameters of the surveillance camera itself, the lens focal length of the surveillance camera also has a huge impact on the effect of video imaging. The smaller the focal length of the lens, the larger the field of view, the more suitable for close-range monitoring; The larger the focal length of the lens, the smaller the field of view, and the more suitable for long-term monitoring.

Summary of requirements, the C3W model camera developed by Haikang Vision Was selected as the surveillance camera. When it uses a 2.8-mm focal length lens, can obtain a monitoring distance of 0 to 15M and has a monitoring field of view of up to 130°. When it uses a 6mm focal length lens, the maximum effective monitoring distance is already close to 40m.

2.2. Layout of surveillance cameras

A computer host can handle a limited number of surveillance videos at the same time, the more cameras are deployed during the layout of the camera, the more image sources are obtained, and the more hosts are eventually needed. The fewer the number of people in a single image source, the lower the performance requirements for each computer host; On the contrary, the fewer cameras are set up, the fewer sources of surveillance images, and the smaller the number of hosts are need. More people in each surveillance video, and the higher the performance requirements for each host is required. How to balance the number of hosts with the requirement of performance and to determine the number of cameras is the key problem.

When setting up the camera, it is necessary to ensure that the surveillance scope of the camera can cover all the area of the swimming pool. In addition, it must also ensure that each computer host can operate steadily and effectively when performing image analysis, the program crashes or long periods shutdown are not allowed, which will cause the miss or delay in issuing a rescue alert. When installing the camera, the appropriate camera installation location should be found firstly, and the height of the location from the pool water surface should be measured, and the appropriate camera lens focal length is determined by the height.

Take the national standard swimming pool as an example. In general, the national standard swimming pool is 50 meters long and 21 meters wide. The water surface height is generally 8 to 12 meters from the top of the room. The height of the water surface is generally 8 to 12 meters from the top of the room. The distance between the camera installation and the water surface of the pool should be about 10 meters. Therefore, a 6mm focal length lens can be considered. The shooting area of the 4 mm focal length camera is an area of 16m*12m. After a variety of layout tests, if you use only a 4mm focal lens camera, it is difficult to design a layout that completely covers the pool and does not have much overlapping area, so 15 6mm lenses are used.
3. Sample set of data for drowning judgment

3.1. Human drowning feature judgment

When drowning occurs, if the drowning person can be found within the first 10 seconds of drowning and the rescue can be completed within 30 seconds, the probability of eventual drowning is extremely low. However, if the drowning state lasts more than 30 seconds, the probability of drowning will increase significantly with the increase of drowning time. According to this rescue time criterion, the threshold setting of the system detection parameters is completed. After recognizing the performance of drowning and the rescue situation, this paper proposes four parameters for the detection of drowning: the length of time accumulated when the body is immersed in water, the speed of the horizontal direction, the area of the body area outline, and the length of time accumulated when the body is upright.

(1) Cumulative length of body immersion in water

Size of this threshold is set in two different cases. First, considering that some swimmers have higher swimming skills and can swim in the water for a longer period of time, this time-length threshold can be set to 50s for swimmers whose body is completely immersed in water and whose horizontal speed is not below a certain threshold. Second, for swimmers who are completely immersed in the body and maintain a lower horizontal speed, this time-length threshold is set to 20s.

(2) Speed in horizontal direction

When the human body is drowning, the speed of the body in the horizontal direction does not exceed 1.5 m/min, that is, the movement distance within 20 seconds does not exceed 0.5 meters, taking into account the unconscious stroke and the push of the water wave. Therefore, we define a swimmer with a displacement distance of no more than 0.5 meters within 20 seconds as a low-speed swimmer.

(3) Area of body area profile

When the human body is drowning, because the torso part will become upright, and the hands and feet will unconsciously do strokes and climbing. The result of this action is that the swimmer's body outline area is small and the area of the swimmer's body outline will change rapidly in a short period of time. Therefore, the size of the human contour area and the range of changes within a certain period of time can also be used as test parameters.

(4) Accumulated length when the body is upright

There are only two situations in which the body's torso remains upright in the pool, namely normal upright and walking and abnormal drowning. Considering the time limit for rescue when drowning, this cumulative time threshold is generally set to 20 seconds. When the ratio of the long axis to the short axis of the swimmer's outline ellipse is less than 1.5, the swimmer's body is considered to be upright.

Through the above four evaluation parameters, combined with the actual performance of drowning, the drowning logical reasoning judgment is designed as shown in Table 1. Event A represents a low level of speed. Event B represents a higher straightness of the torso. The C event represents a higher area change rate and the D event represents a longer immersion time.

| A event | B event | C event | D event |
|---------|---------|---------|---------|
| A event | /       | drowning| drowning|
| B event | /       | drowning| drowning|
| C event | drowning| drowning| /       |
| D event | drowning| drowning| drowning|
3.2. Extraction of Human Motion Parameters

(1) Judgment of the state of the body in the water.

The degree of contrast and saturation in the human body can be used to determine whether the human body is completely immersed in water. The saturation $S$ can be extracted by the RGB2HSV algorithm, while the contrast $V$ can be obtained by equ.(1). If the target area pixel set is $f(x, y)$, then

$$ V = \sqrt{\frac{1}{N} \sum_{x=1}^{N_x} \sum_{y=1}^{N_y} f^2(x, y) - \left[ \frac{1}{N} \sum_{x=1}^{N_x} \sum_{y=1}^{N_y} f(x, y) \right]^2} $$

in where, $\frac{1}{N} \sum_{x=1}^{N_x} \sum_{y=1}^{N_y} f(x, y)$ is the average brightness of a pixel.

(2) Calculation of the speed of movement in the horizontal direction

The minimum external rectangle of the human figure is obtained by using the minboundrect function of MATLAB and the position of the human body is represented by using the central point. After obtaining the position of the human body's center of mass, the human body can be represented by the center of mass, and the displacement of the center of mass between certain frames can be calculated. Let the position of the center of mass is $(x^t, y^t)$ at T time, and the position after N frames is $(x^{t+n}, y^{t+n})$,

$$ v^{t+n/2} = \sqrt{(x^{t+n} - x^t)^2 + (y^{t+n} - y^t)^2} $$

(3) Calculation of change area and rate of the body profile

When requesting the area R of a human image area, the minimum external rectangle of the human image area can be established first and burglarized. At this time, the gray value of the human image area is 1, and then the pixel count is calculated by equ.3 to obtain the area.

$$ R = \sum_{(x, y) \in R} 1 $$

(4) Judgment of the state of the body's upright degree

When the human body exercises in the swimming pool, whether it is normal swimming or standing, or drowning, the minimum external ellipse is the fitting method, which fits the outline of the human body. If R is the human image area, and the total number of pixels in the R area is N. $(x, y) \in R$, the center of mass of the ellipse is $(x_c, y_c)$, $x_c = \frac{1}{N} \sum_{x} x$, $y_c = \frac{1}{N} \sum_{y} y$.

The $(P, Q)$ order center distance and the main axis angle of the ellipse are:

$$ \mu_{p,q} = \sum \sum (x - x_c)^p (y - y_c)^q $$

$$ \theta = \frac{1}{2} \tan^{-1} \left( \frac{2 \mu_{1,1}}{\mu_{2,0} - \mu_{0,2}} \right) $$
The maximum and minimum moment of inertia of the ellipse is:

\[
I_{\text{max}} = \sum \sum \left[ (y - y_c) \sin \theta - (x - x_c) \cos \theta \right]^2
\]

\[
I_{\text{min}} = \sum \sum \left[ (y - y_c) \cos \theta - (x - x_c) \sin \theta \right]^2
\]

(6)

The ratio of the Elliptic major axis to the minor axis can be expressed as: \( L = \frac{I_{\text{max}}}{I_{\text{min}}} \). When the human body swims normally, the ratio will be relatively large because the body is approximately parallel to the horizontal plane. When a person stands still in the water, walks normally, and drowns, the ratio is smaller. When it is less than 1.5, the swimmer is considered to be upright.

4. Hardware and software implementation of monitoring System

The monitoring and alarm system is based on the DSP system, image processing technology and wireless alarm technology. The overall system structure block diagram is shown in Figure 1.

![Figure 1. Structure block diagram of development board of monitoring system.](image1)

Figure 2. Video Acquisition System Based on High Speed DSP.

The data processing part is completed by high-speed DSP as shown in Figure 2. Firstly, the analog video signal received by antenna is decoded by video decoder and transmitted to CPLD/FPGA. CPLD/FPGA writes the data into FIFO and controls the input ratio of video frames. Then, data buffering and buffered video are completed in FIFO. It will be sent to the DSP for processing, then the processed video data will be transmitted to the video encoder, and finally the encoded video will be transmitted to the output device to achieve video output [11]. The hardware part of the design is
TMS320DM642, which is a series of Da Vinci products of TI company [12]. The wireless transmission module is mainly composed of 2051 single chip computer, PT2262 encoding chip and MAX7044 radio frequency transmitter chip. And watchdog chip MAX813L, serial communication level conversion chip MAX232 and other components [13, 14]. Based on the information of various devices and related circuits, a simplified wireless signal transceiver can be designed. The physical object is shown in Figure 3. After testing, the simple transceiver can basically achieve stable data transmission without losing packets in a complex terrain about 50 meters apart.

Figure 3. A simple physical picture of the transceiver.

As is shown in Figure 4, the signal receiving circuit system uses a light emitting diode and a buzzer to use the common cathode. When the P89LPC 935 P2.2 pin is high, the diode and the buzzer are connected, thus realizing the alarm function. Assuming that the shooting area of all surveillance cameras divides the swimming pool into four areas [15-17]. The monitoring video in each area is processed by a host, there will be four wireless signal transmission modules and four receiving modules. The rescue signal for each module represents only swimmers at risk of drowning in the area, and the acoustic and optical alarm circuit is designed as shown in Figure 5. Connecting D0 ~ D3 to the P2.2 pin of the LPC 935 MCU in each receiving module, any receiving module can trigger the corresponding diode to make it glow and activate the buzzer to sound the alarm. In order to complete the alarm functions.

Figure 4. Signal receiving circuit.
5. Conclusion
The recognition and monitoring system focuses on real-time acquisition of motion data, accurate identification of drowning characteristics, rapid transmission of alarm signals, and timely start of rescue mechanism. The wireless antenna data acquisition system ensures the accuracy, efficiency and comprehensiveness of the monitoring. The data processing module makes the whole system easy to install and debug, and can adapt to the complex and harsh underwater environment. The video image processing algorithm can accurately extract the movement characteristic information of the athletes and send out the alarm signal quickly. It can transmit the specific alarm area to the lifeguards to ensure the timely start of the rescue mechanism and avoid drowning. This system is not only applicable to the motion monitoring of swimming venues, but also to underwater safety operations, underwater biological monitoring and other work scenarios. It can effectively reduce the occurrence of underwater casualties, and has broad market application prospects and important social significance.

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