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Research on non-invasive psychological detection technology based on artificial intelligence

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Abstract: *The studies on polygraph technology in China started in the 1990s, after nearly 30 years of research and practice, great progress has been made in technical methods, technical equipment, and the development of effective detection indicators, especially Multi-channel polygraph technology has been widely used in the fields of public security, prosecution, and law enforcement etc., with many successful use cases. But there are still many bottlenecks that are preventing the adaption of polygraph technology in the other areas. With the recent development of new technologies such as big data, machine vision and deep learning, new opportunities have been brought to solve historical issues. This article proposes a new psychological detection solution by leveraging these new technologies, specifically, we are proposing to use non-invasive technique, i.e., video based machine vision and deep learning, to measure the physiological indicator that cannot be controlled by subjective consciousness, which, combined with other indicators such as expression recognition, and big data, provides a better and more accurate multiple dimension psychological indicator recognition solution. This paper attempt to discuss the technical principles, system design, and application of this new solution.*

Keywords: *non-invasive physiological index recognition, psychological recognition, emotion recognition, machine vision, deep learning, big data*

1. Research background and questions raised

Emotions are the change of psychological and physical condition that are generated accompany with the process of cognition and consciousness, playing a very important role in human communication. There is a long history for research on emotions. In recent years, with the development of machine vision technology and big data technology, the realization of non-invasive emotional computing through video has gradually become the frontier field of emotion research. Specifically, emotional computing is a computing model established by constructing emotional states. It analyzes behavioral and physiological signals, establishing emotional interaction between human and machine based on the measured physiological state. Its core goal is “emotion recognition”, that is, to evaluate the corresponding emotional state through the user’s behavior and physiological response. This technology requires algorithms such as machine vision and deep learning as back support. With the help of dedicated data acquisition equipment, it can quickly capture the physiological indicators, micro-expression movements, physiological characteristics and other data of target object under non-invasive conditions, and the system will automatically give quantifiable emotion recognition results. The system provides users with scientific and quick decision making based on different application scenarios, especially for emotion recognition of nervousness and anxiety. Because this technology can achieve rapid automatic identification, and it is non-invasive data collection, which greatly expands the application scenarios. It will not only be used in the field of lie detection in litigation, but also in many other public security fields.

2. Research content

2.1 Theoretical model

Corresponding to different emotion induction methods, emotion recognition methods are also different. Common methods to complete emotion recognition based on machine vision are mainly divided into two categories: recognition based on non-physiological signals and recognition based on physiological signals.

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The emotion recognition method based on non-physiological signals is mainly the recognition of facial expressions, which can also be called “expression recognition”. The basic principle of facial expression recognition is through machine learning, which is to let the computer model learn in advance the facial images that have been emotionally labeled. After a large amount of data “training”, the model can be used to identify different facial expressions. This is also the basic principle of most current emotion recognition technologies. There are natural defects in judging people's emotions based on the principle of facial expression recognition: people can disguise their real emotions by disguising facial expressions, which are often difficult to be discovered, affecting the reliability of emotional recognition. Therefore, this type of technology can only be applied to some pan-entertainment scenarios such as advertisement, but in areas that require strict accuracy of results, such as psychological supervision, border inspection, customs screening, and public security law suspects polygraph detection, there is a relatively high risk of misjudgment in the use of technology based on facial expression recognition for psychological testing.

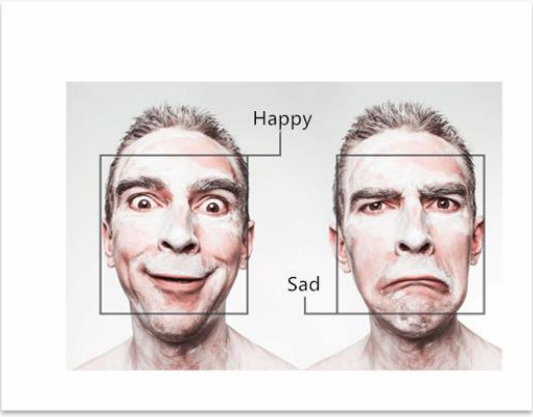

Figure 1: Facial expressions cannot truthfully reflect emotions

Table 1: The performance of sympathetic nervous excitement

organ		sympathetic excitation
pupil		mydriasis
lung		Bronchiectasis increases oxygen intake, slowed, shallow breathing with the body at rest.
heart		Increased contraction, increased blood pressure and increased blood supply
Sweat glands	limbs	Sweating, increased tactile and grip strength
	body	decrease in body temperature
liver		Secret glycogen, increases the blood glucose supply to the Cardiac and skeletal muscle
Peripheral blood vessels		Contraction, blood supply to the Cardiac and skeletal muscle
Cardiac muscle, skeletal muscle		Blood supply increases
Adrenal gland		Secret adrenaline, strengthen the role of sympathetic nerves, excite all the above organs
erectores pili		Excitement, goose bumps, hairs on end
digestive system		Inhibition, vasoconstriction, blood supply to the skeletal system
reproductive system		Inhibition, vasoconstriction, blood supply to the skeletal system
Bladder		Bladder buckle and sphincter relaxation, bladder urinary muscle tightening

The emotion recognition technology studied in this paper mainly adopts the emotion recognition method based on physiological signals. This method mainly studies the relationship between the changes

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of physiological indicators aroused by the autonomic nervous system and the micro-actions/micro-expressions and human emotions. The main characteristic of the response to autonomic nervous system arousal is that it is not controlled by subjective consciousness. These changes in physiological signals cannot be concealed, as has been demonstrated in the medical field, including traditional multichannel testing devices. The sympathetic nerve is equivalent to the human body's rapid response mobilization system, and the increased sympathetic nerve activity is related to the physical indication of "autonomous awakening". Parasympathetic nerves regulate processes that change slowly, such as rest, digestion, and so on. Therefore, when people are nervous, such as quarreling, lying, etc., the sympathetic nerve is rapidly activated, which directly leads to the accelerated metabolism of the human body, skin sweating, heart rate increased, blood pressure and other physiological phenomena. However, when a person recovers, the parasympathetic nerve is activated and the metabolism level drops, which directly leads to physiological phenomena such as drop in skin sweating, drop in heart rate, and drop in blood pressure. [1] [4] [5] [6] [7]

Figure 2 also draw a similar conclusion that changes in physiological indicators such as skin electricity, heart rate, and pupil size are directly related to whether someone is lying or not. [2]

TABLE 1

Frequency of detection

Subjects	Skin Resistance					Pupil Size Change					Heart Rate Change				
	Control Question			Guilty Knowledge Test		Control Question			Guilty Knowledge Test		Control Question			Guilty Knowledge Test	
	D[a]	ND	I	D	ND	D	ND	I	D	ND	D	ND	I	D	ND
Innocent	58	13	25	57	39	33	21	42	32	64	34	20	42	43	53
Guilty	9	56	31	11	85	30	25	41	19	77	19	32	45	17	79
	$\chi_2^2 = 64.62^*$			$\chi_1^2 = 46.11^*$		$\chi_2^2 = 0.50$			$\chi_1^2 = 3.84^*$		$\chi_2^2 = 7.06^*$			$\chi_1^2 = 15.15^*$	

[a]D = deceptive, ND = non-deceptive, I = inconclusive.
$^*p < .05$.

Figure 2: The relationship between electrical skin/heart-rate/pupil size and lying

Researchers at MIT have also come to a similar conclusion that the skin electricity and heart rate variability have great changes during tension / lying. Krumhansl, professor of cognitive psychology at Cornell University in the United States, also summarized the relationship between happiness, sadness, and fear in physiological indicators. [3] As shown in Figure 3:

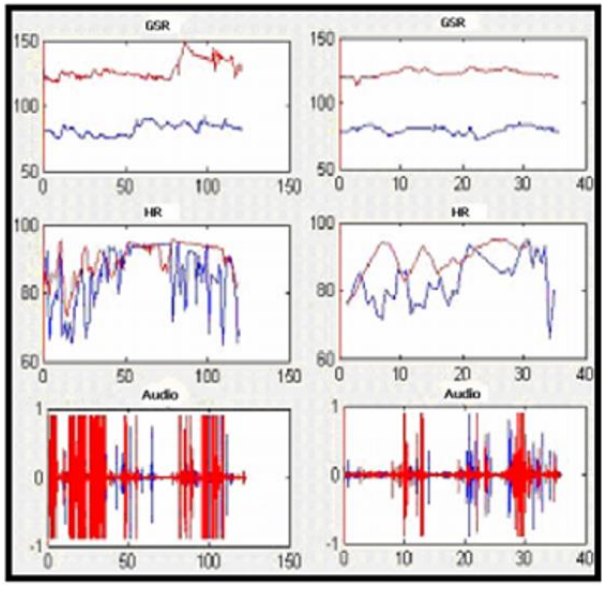

Figure 3: The relationship between electrical skin/heart rate/voice and lying
(left picture shows people who is lying, the right picture shows normal people's situation)

2.2 Key technology

Based on the above theoretical model, the main research content of "non-invasive psychological

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detection technology " can be focused on the following key scientific issues: 1) How to use non-invasive machine vision algorithms to measure physiological indicators that cannot be controlled by subjective consciousness; 2) How to build a multi-modal deep learning model based on physiological indicators, which integrate other related information such as micro-expression, micro-action, speech, text, etc. to evaluate psychological indicators; 3) Comprehensive use of big data technology to realize emotional cognition.

2.2.1 Non-invasive machine vision algorithm

Changes in human heart rate, blood oxygen, and blood pressure can all be inferred from changes in the speed and phase of blood flow in capillaries. A simplified optical model is shown in Figure 4, from the model, it can be seen that the main research task is to use the image sensor to collect the scattered light from the capillaries, and to restore theses physiological indicators through machine vision algorithms.

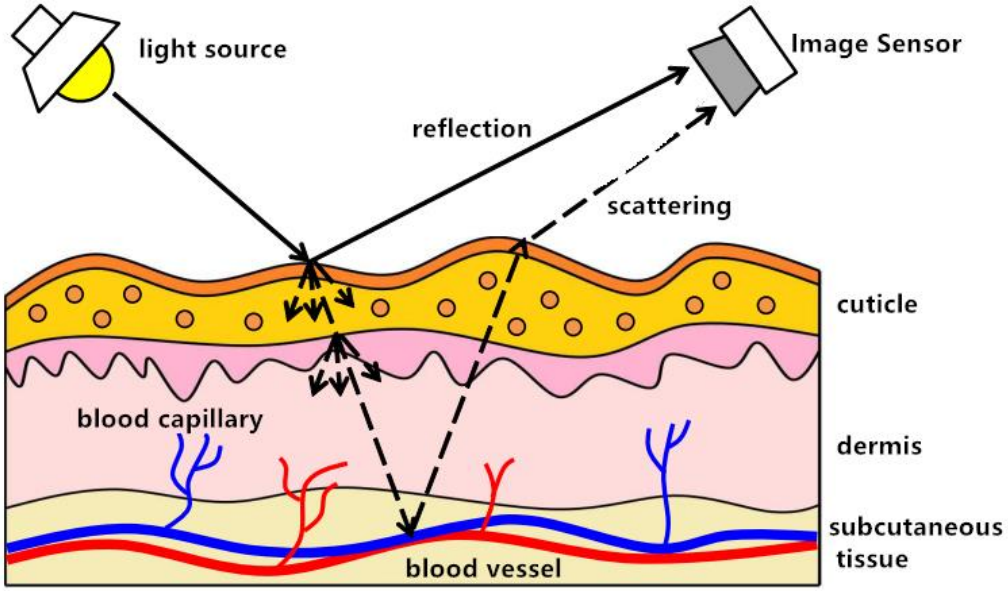

Figure 4: Optical model of image recognition [8]

Considering that the different image sensor reacts to light sources of different wavelengths, we can assume that the emitted light source signal is $I(t,\lambda)$, We could build a model $I(t,\lambda)$, as a signal that changes according to time changes with considering different application scenarios(λ is the Wavelength of the light origin). Then the *kth* pixel of the image sensor, the signal $C(t,\lambda)$ received at the time *t* can be written as:

$$C_k(t,\lambda) = I(t,\lambda) \cdot \left(v_s(t) + v_d(t)\right) + v_n(t)$$

And λ is the wavelength of the light source, usually unchanged

$C_k(t,\lambda) = \begin{matrix} R_{k,}(t,\lambda) \\ [G_k(t,\lambda)] \\ B_k(t,\lambda) \end{matrix}$, R/G/B represents the response of R, G, and B channels respectively. For example, $R_{k,}(t,\lambda)$ represents the response of the red channel when the wavelength of the corresponding emission source is λ at time t.$v_d(t)$ and $v_n(t)$ stand for reflected and scattered signals respectively. Among them, physiological indicators are included in $v_d(t)$,$v_n(t)$ stands for noise.

Using the Robust PCA method, the three channels of R, G, and B, are the signals related to changes in physiological indicators can be recovered firstly. On this basis, data such as heart rate, blood oxygen, and blood pressure changes are obtained. As shown in Figure 5:

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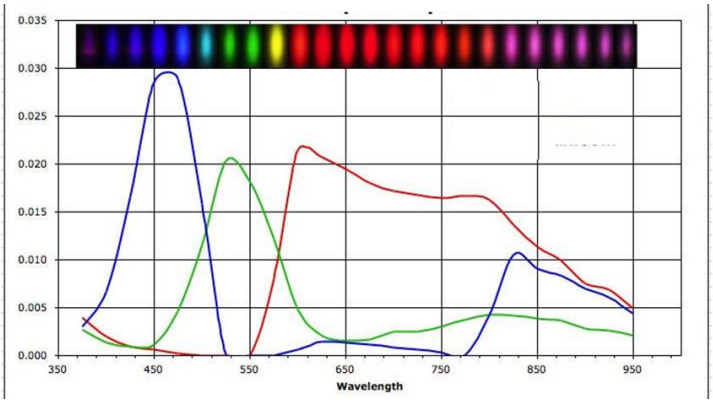

Figure 5: Corresponding changes between R, G, B channels and physiological indicators [9]

2.2.2 Multi-mode deep learning mental emotion perception algorithms

This includes several key factors such as the analysis of the physiological / psychological relationship between different groups of people and the acquisition of training data, the choice of emotion models, and the selection of deep learning architecture.

- Analysis of physiological and psychological relations among different populations: The research on the relationship between physiological and psychological fluctuations among different populations is of great help to the development of deep learning algorithm. The correlation between qualitative and statistical physiological indicators and psychological indicators can be obtained by using relevant medical and psychological research results for different populations.

- Acquisition of training data: the accuracy and comprehensiveness of training data is the key to deep learning algorithms. For example, the relationship between changes in physiological indicators of different groups of people (such as gender + age) and changes in emotional indicators can be simulated by simulated crime scenes widely used in the field of applied psychology. Meanwhile, when the target object generates stimulation (answering questions), the instrument records its real-time physiological indicators, and the target object records its real-time emotional indicators. At the same time, it records synchronized images, videos, and audios to obtain their physiological characteristics, micro-actions, micro-expressions, voice, text, etc. later.

- Emotion model selection: to identify emotions. Firstly, you need to make an effective and reasonable classification of emotions according to certain characteristic standards, and then study the nature of characteristic parameters on the basis of different categories. At present, the classification of emotions in academia is mainly studied from two aspects, one is from a discrete perspective, and the other is from a continuous dimension. This research model is mainly based on the latter.

- Multidimensional emotion detection deep learning algorithm: the current widely used network (CNN) lack of sequence data processing ability, considering the mood is a continuous time series data, need to adopt different network architecture to testing on mood. As shown in Figure 6:

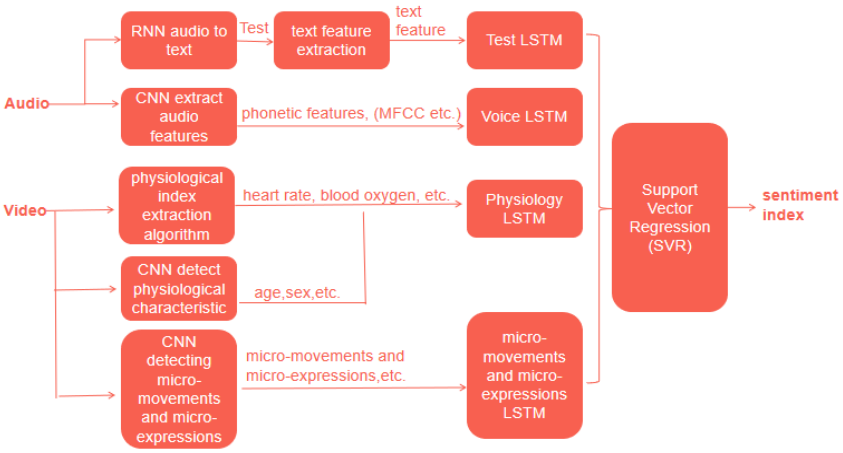

Figure 6: Network architecture

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2.2.3 Comprehensive use of big data technology to realize emotional cognition

At the present stage, the application of "non-invasive physiological and psychological detection technology" in personnel review in China has not formed a system, and most of the application is judged by some experienced investigators according to their long-term responses to the target objects. The use of big data technology to achieve emotional cognition, facial expression, voice, behavior, text, physiological signals and other aspects of comprehensive recognition, quickly and automatically judge the user's emotional state and emotional changes, no doubt can greatly improve work efficiency.

1) A clue offline analysis method that combines big data technology and deep learning

The storage and analysis of multidimensional data are mainly divided into two categories: real-time and offline. Offline analysis is mainly used to review real-time surveillance or other video recordings (such as crime scene recordings). It can intensively capture and analyze a large number of video files, analyze micro expressions, analyze the narrative content to help find out the relevant target objects and provide more clues.

2) Lie recognition method based on multi-dimensional data fusion

Real-time analysis is mainly used for review, comprehensively using multi-dimensional data sources, through rapid analysis and retrieval, to help reviewers quickly analyze the subtle changes of the target object, not only improve the rate of lie recognition, but also improve the accuracy of lie recognition.

3) Real-time warning method based on multi-dimensional streaming data fusion

Perform real-time streaming statistical analysis of emotion tags, record and learn normal expressions and abnormal expressions at different frequencies, and provide real-time alarms according to given rules.

2.3 Realization of function

Based on the above principles, image processing, algorithm models and data analysis are deeply studied, and specific system products can be realized by using software and hardware development. For example, in the field of public safety, the “non-invasive physiological and psychological detection system” can monitor and pre-warn the target’s physiological and psychological indicators in a non-invasive form in the process of conversation an inquiry. Through the network deployment, with the emotion identification in the on-site conversation as the core and the remote command as the auxiliary, the standardization of the law enforcement process, the electronic case management, the flattening of the review command, and the intelligence of the emotion analysis are realized. Concrete can be realized:

- Adopting a fully networked architecture to facilitate centralized management and remote invocation. At the same time, the networked architecture provides the possibility to integrate all data sources.
- Different from face image comparison, through calculation and analysis of physiological indicators, physiological characteristics, micro-actions, and micro-expressions, the true emotional response of the target object can be deeply revealed without being deceived.
- Real-time detection and tracking of physiological signals such as heart rate, heart rate variability, blood oxygen, blood pressure changes, and body temperature of the target object through non-invasive machine vision, so as to realize real-time physical and mental monitoring of the target object.
- Through non-invasive machine vision, in the free talk mode, real-time physical, psychological and emotional detection and tracking of the target, automatic screening of sensitive issues that the target object is concerned about, and real-time warning to the examiner through the wireless bracelet.
- Integrate authoritative psychological detection methods and theories in the industry such as CQT, GKT, POT, etc., and can implement expert-level psychological detection and in-depth analysis.

3. Application prospects

Considering the existing literature, research of emotion recognition based on physiological signals is currently in the stage of transformation from theory to practice, which are many studies, but it’s mixed. Due to the difference in emotion-inducing materials, collection equipment, feature extraction of physiological signals, dimensionality reduction and classification algorithms, the accuracy of emotion recognition in existing research varies, and horizontal comparisons can’t be made. Therefore, future

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emotional research can be carried out from the following two aspects: First, researchers will use standardized stimulus materials, especially film clips and music videos with higher ecological validity, and in the future, it is expected to establish a standard library of Chinese film clips and music videos applicable to Chinese social and cultural backgrounds. Second, researchers use publicly published physiological signal databases (such as the DEAP database) to develop feature extraction algorithms, classification algorithms and models, which can not only avoid the differences in the process of emotion induction and signal acquisition, but also facilitate the horizontal comparison of various algorithm models by researchers.

Based on the research of "artificial intelligence-based non-invasive psychological testing technology", a corresponding non-invasive personnel review / screening assistance system can be developed, which can integrate all the most advanced case handling equipment in the existing technology case handling, and psychological tester, psychological tracker, voice analyzer, facial expression analyzer, EEG tester, vital signs monitoring and other functions are highly integrated. It is a revolutionary innovation to traditional case handling and personnel screening methods, which can fill the gaps in domestic related technical research.

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