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New method for correct identification of structural elements of ancient hieroglyphs

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Abstract. A new method for the correct identification of various complex structural elements of ancient hieroglyphs is described. The method is based on photometry of the studied surface of the ancient artifacts. The obtained data are converted into digital form in order to determine the characteristics and parameters characterizing the properties of the investigated artifact surface. Digitized data is processed in various graphic applications, including those working with vector images. Several control experiments were also carried out. In particular, the corresponding statistical characteristics and parameters of the studied artifact surface profiles were determined. The data obtained made it possible to unambiguously detect the ancient hieroglyphs on the artifact surface and determine their number. Described method of studying ancient artifacts makes it possible to obtain sufficiently reliable results that will undoubtedly be useful and promising in the study of ancient hieroglyphic signs. Our research method is characterized as: non-contact, informative, and sensitive. This testifies to its importance and prospects in the study of similar ancient artifacts.

Key words and phrases: hieroglyphic inscription, structural elements, surface, photometry, statistical characteristics and parameters, Jiăgŭwén, Jīnwén, Chinese radicals (bùshǒu), computer data processing

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1. Introduction

Writing on bronze vessels (Jinwen) and tortoise shells and fortunetelling bones Jiaguwen relate to the oldest examples of art and culture [1–10]. They are unique in their own way. Jiaguwen (甲骨文 / Jiăgŭwén, XIV–XI c. BC) are hieroglyphic inscriptions fixing the results of fortune telling or predictions [3, 6–9].

Bronze vessels Jinwen (jīnwén / 金文, the earliest of which date back to the end of 2nd millennium BC) belong also to the most ancient samples of Chinese history, linguistics, archeology, and science [4, 7, 8]. These ancient objects are often poorly preserved, but these objects are of great historical, cultural and scientific value [11]. Basically, their research is devoted to the study of hieroglyphic inscriptions written in the surface in order to interpret their contents, as well as the identification of ancient keys (hieroglyphs) or Chinese radicals (bùshǒu / 部首).

Figure 1. An example of Jiaguwen (甲骨文, “Turtle shell inscriptions”)—hieroglyphic inscriptions fixing the results of fortune telling or predictions. Vertical lines in the center: “1” corresponds to the central part of the investigated surface of the shell, where there are no hieroglyphs; “2” corresponds to the investigated part of the surface of the shell, where there is a column of ancient Chinese hieroglyphs

The present paper is devoted to the development of a new method for solving some problem for recognition of ancient artifacts [7, 12]. Using digital photometric data of the artifact relief, this method allows determining various characteristics and parameters, including statistical ones, characterizing the properties of the studied ancient surface, e.g. Jiăgŭwén, jīnwén [7, 11–20]. The main task of the work is to reveal the possibility of correct identification of groove-type elements that are an integral part of various structural surface elements. In technical applications, these elements can be various single grooves, which are the constituent elements of such widely used structures as diffraction gratings and grating’s type structures. In the study of the oldest artifacts, for example, Jiaguwen or Jinwen, there is a need to study ancient hieroglyphs written on the surface of a tortoise shell, copper vessel or stone [3, 4, 6–9].

2. Materials and methods

This article uses a new statistical method of research, which can be a good addition to the currently used traditional methods (mainly visual) of research [8, 9, 11–18]. This method allows using various digital photometric data on the surface of the shell (see Figure 1) to determine various characteristics and parameters characterizing different properties (including statistical) of the investigated surface [8, 12].

The main advantages of our research method are: contactless, informativeness, non-destructivity, and potentially high enough resolution (for example, according to the statistical parameters of the surface profile). This allows us to talk about its promise in the study of such ancient art and culture as Jiaguwen. The main goal at this stage of the study is to demonstrate the possibility of a certain identification of ancient hieroglyphs written on the surface of the tortoise shell using the obtained digital surface profiles of the test sample.

It is important to emphasize that the results obtained allowed us to solve the formulated problem of identifying the studied surface images, namely, to determine approximately the number of ancient Chinese radicals placed on the scan line of the surface profile with hieroglyphs. It is shown that the discrepancy with predetermined number of hieroglyphs does not exceed 10%. At this stage of the study, the results obtained can be considered good.

Our method is based on photometry of artifact surface profiles, in which a sample of brightness levels in a discrete set of points is carried out with subsequent conversion to digital form [7, 11, 12]. Photometric data of the surface profile can be obtained using for example "Fiji ImageJ" program for Windows [7, 11–16]. The obtained data are digitally processed in order to determine the characteristics and parameters characterizing the properties of the researched artifact (see Appendix) [7, 11, 12].

We utilize different research methods including a statistical approach, which allows us to find the characteristics and profile parameters of the test sample according to photometry of its surface [7]. This research method will finally solve an important inverse problem of pattern recognition: find the number of characters in the studied sections of the surface profile, as well as identify a solitary micro-object of the groove type. Properties of these structures will be useful in further research of different type ancient hieroglyphs, for example Chinese hieroglyphs (see Appendix).

The use of digital methods for processing large amounts of experimental data, for example, using such well-known signal processing methods as the fast Fourier transforms or wavelet transform, undoubtedly allows us to obtain new interesting results [7, 12]. However, we should note that these studies are quite expensive and time-consuming.

Figure 1 shows a processed photo of a shell, which is one of the objects under study. The images used in this paper are taken from open sources and are used as illustrations [4, 6, 7, 9, 11].

The subject of the study is the ancient shell with or without hieroglyphs written on it surface by the antique scribe. Major attention is paid to the improvement of innovative methods for the correct identification of the same type of hieroglyphic signs in the ancient hieroglyphic inscriptions according to the typical digitized data. The solution of this key problem makes it possible to avoid mistakes at the initial stage of the study. As a result, at all subsequent stages of research it becomes possible to examine the accurate data. Finally, when the correct recognition of hieroglyphic signs is carried out, one can obtain the quantity of ancient hieroglyphs.

3. Results

Our main goal is to find the quantity of ancient Chinese hieroglyphs (radicals / bùshǒu / 部首) $\mathfrak{I}$. For this purpose we propose several procedures (see Appendix) [7, 12, 14, 15]: 1) as an initial estimate – an integral method that permits to define the number of grooves (structural elements of hieroglyphic inscriptions) on the scanning line; 2) division the scan interval length L of the artifact profile to the correlation radii r, characterizing the statistics of these profiles; 3) numerical Fourier transform of the photometric data of the surface profile.

Indeed, the correlation radius determines the characteristic size of the "particles" of scatterers on the surface of the object under study [7, 12]. These "particles" should not be taken literally. This term is used to indicate the area within which correlation takes place, i.e. areas of "distortion" of the surface. In our case, this distortion is created by the ancient hieroglyphs; therefore, our estimate $\mathfrak{I}$ is quite fair. The approximate average length of the scan line of the surface profile of the shell: $L = 18$ cm. In this case, both shorter and longer sections were used in the calculations.

Let us make a remark about which correlation radius should be taken in the calculations. Formally, one need to take the correlation radius defined for the surface profiles of the shell with hieroglyphs. However, it is necessary to take into account the certain contribution of a surface free of hieroglyphs, since its role in the formation of the final profile is undoubtedly also present.

Note that to solve this problem, it is not necessary to determine the rms height with high resolution, it is sufficient that the signal-to-noise ratio level allows for the reliable identification of the presence of the relevant objects (hieroglyphic signs) on the surface of the test sample.

As an initial step, the following approach can be proposed. Where a sufficiently dense arrangement of ancient Chinese radicals is visually observed, the contribution of a surface free of hieroglyphs will be taken into account to a lesser extent. Given the statistical approach in our analysis, for simplicity, we will find the average of two estimates of the correlation radii: for surface profiles without hieroglyphs and with hieroglyphs. The data obtained above for a comparative analysis of the graphs in Figure 2 and Figure 3 confirm the validity of this approach (see Appendix).

Therefore, we will determine the number of ancient Chinese hieroglyphs by the following simple formula [12]:

$$\Im = L/\bar{r}. \tag{1}$$

Let's find the average value of the correlation radius $\bar{r}$, taking into account the above: $\bar{r} = (r_1 + r_2)/2$, where r_1 is the correlation radius of the shell surface, where there are no hieroglyphs, and r_2 is the correlation radius of the shell surface, where there is a column of the ancient hieroglyphs (see Figure 1). We take into account a Gaussian approximating correlation function. We can find currently $\bar{r}$: $\bar{r} = [(25.7 + 2.9)/2]\,\text{mm} = 14\,\text{mm}$.

Now we can finally find the approximate number of Chinese radicals in accordance with the given above formula (1):

$$\Im = 180/14 = 13. \tag{2}$$

So, we found from equation (2) that the number of ancient hieroglyphs (or ancient Chinese radicals (部首 / bùshǒu)) is equal to 13. According to our preliminary data, this vertical scan line (marked with the number "2" in Figure 1) contains 12 hieroglyphs.

Thus, the value close to the exact quantity of Chinese radicals was determined: error is 8.3%. If the length of the scan line changes, the number of ancient hieroglyphs changes a little too. Indeed, if in calculations according to formula we take not the average value L, and the dimensions of the used scanning lines of the shell vertically in different sections (with a horizontal shift), and take others r, we obtain that $\Im$ may vary from about 11 to 15. Consequently, the greatest error in finding the number of radicals $\Im$ will be approximately 25%. At this stage of research, such an error can be considered quite acceptable.

4. Conclusion

It is important to emphasize that the results of the work made it possible to finally solve the recognition problem posed, namely, to determine the number of ancient hieroglyphs on the artifact under study. It is shown that the discrepancy with the specified number of hieroglyphs located on the studied scan lines is less than 10%. At this stage of the study, the results obtained can be considered good.

The advantages of the research method implemented in this work are its non-contact, non-destructive nature, informative value and high resolution in terms of statistical parameters of the surface profile. This indicates its promise in studying such ancient art and culture samples as Jiaguwen or Jingwen—ancient hieroglyphic inscriptions that record the results of fortune-telling or predictions. Moreover, a certain simplicity and clarity of implementation allows it to be used in interdisciplinary research involving specialists from different subject areas of knowledge. The results obtained in the article will undoubtedly be useful in areas such as graphic document processing and applied linguistics, especially in the statistical analysis of ancient hieroglyphic inscriptions. Considering that the most ancient studied samples often have poor preservation, as well as of high historical, cultural and scientific value, our method can be a good addition to the traditional (mainly visual) research methods currently used.

The methods developed in this paper can be used in the future, for example in computer intelligent systems for recognition of text containing large arrays of various hieroglyphic signs. A particularly promising advantage, in our opinion, is the ability to identify the statistical properties of large arrays of studied data. Knowledge of statistics allows, for example, to use the intelligent computer classification of ancient objects under study in a confident way. The results obtained can be useful in linguistics, lexicostatistics and sociolinguistics, especially in the statistical analysis of such old hieroglyphic inscriptions, as well as the information contained in them. Of particular interest may be the study of the relationship between the information contained, for example, in the Jiaguwen or Jinwen and the socio-cultural conditions for the development of the language and society in the corresponding eras.

Appendix

A new research method used in this work allows determining different characteristics and parameters describing the properties of the studied artifact surface [7, 12]. As a result, the form of approximating autocorrelation functions (ACF) can be found, both without hieroglyphs and with hieroglyphs. And the corresponding statistical parameters are accordingly determined: the standard deviation and the radius of correlation of the surface profile irregularities.

The most important statistical characteristic of an uneven surface is *autocorrelation functions*, which characterizes the relationship between the analyzed function and its shifted copy of the shift value of the argument (the process under consideration is stationary).

The most important statistical parameters are the root-mean-square (rms or standard deviation) σ and correlation radius r of surface irregularities. *Root mean square* characterizes the amount of dispersion of the values of a random variable relative to its mathematical expectation, i.e. average value. A larger value of the standard deviation indicates a larger scatter of values in the presented set of values, and a smaller value of it, respectively, shows that the values are grouped around the average value. *Correlation radius* determines the characteristic size of the “particles” of scatterers on the surface of the investigated object. These “particles” should not be taken literally. This term is used to indicate the area within which correlation takes place, i.e. areas of “distortion” of the surface [7, 12].

It is possible to determine the statistical characteristics and parameters describing the properties of investigated surface without involving complex scattering theories, requiring more laborious and subtle experiments and complex calculations than the use of more simple scalar equation (3) [11–15]. However, if necessary, more complex, for example, vector scattering theories and appropriate calculation algorithms can be used [7, 11–15].

Incident and reflected radiation intensities I_i and I_r are related by the next known expression:

$$I_r = I_i \exp\left\{-\left[(\pi h/\lambda)\cos\theta\right]^2\right\}, \tag{3}$$

where h is the height of the surface profile irregularities (e.g. ordinary roughness and hieroglyphs), $h \approx 4\sigma$; $\pi \approx 3.14$; *theta* is the angle of incidence of light on the artifact surface, λ is the radiation wavelength (in the case of non-monochromatic light, one can take, for example, the average value); light intensities incident on the surface and reflected (scattered) from it, satisfy the condition: $I_r/I_i \ll 1$.

From expression (3) we can find the height h of the studied artifact surface:

$$h = \left(\frac{\lambda}{2\pi \cos\theta}\right) \ln(I_i/I_r). \quad (4)$$

Consequently the height of the artifact (surface) profile irregularities is directly proportional to $\ln(I_i/I_r)$, obtained from the photometric data of a certain section of the profile (at the fixed values of θ and λ).

It follows from the expression (4) that to determine the profile heights of the surface under study, it is sufficient to know the values of λ, θ and I_i/I_r.

Since in our case the quantity I_i is also fixed, we assume that h depends only on the intensity I_r of the light reflected (scattered) from the artifact surface, i.e. in accordance with expression (4) the spatial distribution of h is a reflection of dependence I_r (or simply I_i) on the average surface profile: $h \propto h(I) \propto h(y)$. Therefore, by measuring the spatial distribution I, for example, along a certain direction, we can get an average surface profile. In the case of using a statistical research methods, this approach is justified and, moreover, necessary [7, 12].

Now, some approximating autocorrelation function can be found, that characterizes the relationship between the analyzed function and its shifted copy of the shift value of the argument $y = y_1 - y_2$:

$$R(y_1, y_2) = \langle h(y_1)h(y_2)\rangle, \quad (5)$$

where brackets $\langle ... \rangle$ mean (statistical) average.

An approximate estimate of the experimental (empirical) autocorrelation function (5) on a discrete set of points N (sample implementation of an encoded profile $h(y)$, see Figure 1) can be calculated using the following formula:

$$R(mu) = N^{-1} \sum_{i=1}^{N} H(iu)H(iu + mu), \quad (6)$$

where mu is the shift interval, $m = 0, 1, 2, \ldots, M - 1$, where M is number of measured ordinates (counts) of the function $h(y)$.

This procedure is carried out by recording an array of digitized values $h(y)$, followed by their digital processing in accordance with the expression (6). The resulting numerical data allows us to construct a graph of the approximating ACF and determine the corresponding statistical parameters of the irregularities of the artifact surface: standard deviation and correlation radius.

It should be noted that the most accurate (consistent and unbiased) estimates of the statistical characteristics of a random profile can be obtained as an average over the entire ensemble of realizations. It is clear that this will require a significant increase in processing time for all received data.

Now we can give the formulas of two well-known autocorrelation functions that are most frequently used in statistical analysis: exponential and Gaussian. They are often used by researchers to approximate experimental ACFs.

Exponential and Gaussian ACF are described by the following formulas accordingly [7]:

$$R(y) = \sigma^2 \exp\lfloor -|y/r| \rfloor, \quad R(y) = \sigma^2 \exp\lfloor -(y/r)^2 \rfloor. \quad (7)$$

We should note that not only ACFs (7) were used in the research, but also other approximating functions, for example: decaying cosine, logistic (see Figure 2; 1 arb.u. = 100 m), polynomial, logarithmic, etc. In the calculations, we took sections of different lengths, from about 3 to 10 cm. Several results were obtained by averaging over these profiles realizations.

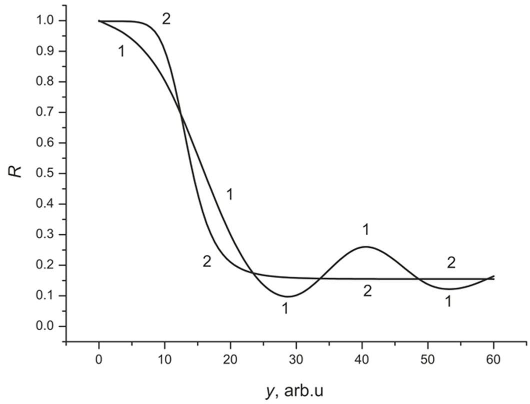

Figure 2. Approximate experimental (1) and logistic (2) normalized functions $R(y)$

As an example Figure 2 shows the logistic fitting function (indicated by the number "2"). To test the method, we used onyx, jasper, and jade specimens, the surface of which is similar to the surface of ancient specimens [9, 12]. These results confirmed the possibilities and prospects of the described method.

It should be noted that a solitary object of the groove type that is a part of the complex element similar to the old hieroglyph can be easy determined if its depth and width are not less than 0.1 mm. We should outline that the groove width must be greater than wavelength of radiation incident on the object under study. A more detailed analysis of this problem, especially the issues of the incorrect inverse problem of restoring the geometric profile of a groove, is beyond the scope of this article. We only note that this problem can be solved using fairly complex algorithms that implement a numerical reconstruction of such geometric profiles, in particular with super-resolution, i.e. exceeding the Rayleigh limit.

The mathematical model of the groove in the broad optical range of wavelengths is described by the next expression:

$$f(y) = \exp\left[-i2kh(y)\right]. \tag{8}$$

The notation in the formula (8) is as follows: $k = 2\pi/\lambda$ is wave number, $\pi = 3.14$; $h(y) = -h$, at $|y| \leq \Delta y/2$ and $h(y) = 0$ at $|y| > \Delta y/2$; h is a groove depth ($h \leq 2$ mm); Δy is a groove width ($\Delta y \leq 1$ mm). In one of the subsequent works, we plan to show the possibility of reconstructing a geometric profile $h(y)$ from its experimentally obtained optical relief $f(y)$ (solution of an ill-posed problem).

Figure 3 shows $I(y)$ (i.e. a profile $h(y) \propto I(y)$) for a line containing ancient Chinese hieroglyphs. As can be seen in the figure, the number of grooves is 39 considering some level of intensity $I \geq 0.15$. If we take into account smaller details, we get a little more: the number of grooves is about 45. In this case, only one groove with number "18" is uniquely identified with the element in the center of the scan line on the surface under study (see Figure 1). Obviously, it is quite difficult to identify all ancient Chinese hieroglyphs based on the data shown in Figure 3 (1 arb.u. = 100 m). One can make only some assumptions about the number of ancient hieroglyphs and/or Chinese radicals (bùshǒu).

To test the method, samples of onyx, jasper and jade were used, which surface is similar to the surface of ancient artifacts. Eventually, several control experiments were conducted, during which the following were investigated: 1) systems of structural elements, similar to the system of elements in hieroglyphic writing on the surface of antique samples, each of which contains elements similar to

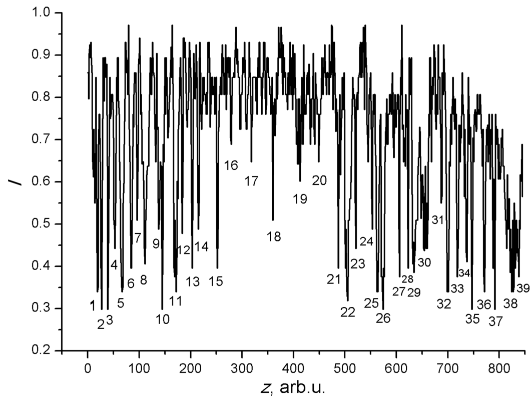

Figure 3. Experimental normalized intensity $I(z)$ along a vertical line close to the line “2” on the Figure 1, where there is a column of ancient Chinese hieroglyphs

Figure 4. Two Chinese hieroglyphs “yué” carved into the onyx surface

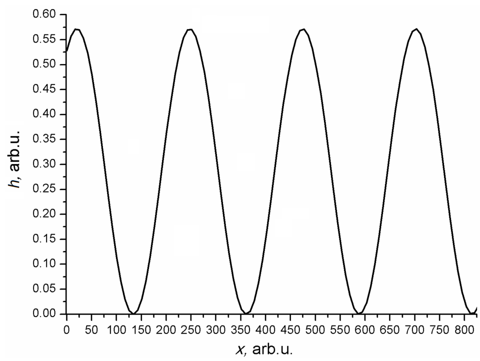

Figure 5. Experimental smoothed approximate profile $h(x)$ along a horizontal line close to the centers of two ancient Chinese hieroglyphs “yué” from the Fig. 4.

a groove; 2) hieroglyphs “yué” – month; meat (depicted on the surface of the sample by the co-authors of this article).

As an example, data are given on the study of two hieroglyphs “yué”, carved with a fine chisel on the surface of onyx (written on the surface by co-authors of this paper). Figure 4 shows a processed photograph of the surface of the onyx sample, which is one of the objects under study (photo of co-authors of this paper).

Figure 5 shows a smoothed approximated curve for the horizontal profile of two ancient Chinese hieroglyphs “yué” (month; meat) depicted on the Figure 4 (photometry was carried out approximately in the middle of hieroglyphs; 1 arb.u. is about 10 m). Digital profiles were obtained using the “Fiji ImageJ” program for Windows. The length of the horizontal scan profile was approximately 1–5 cm (or 200–600 pixels).

We can note that the curve from the Figure 5 can be approximated by the function like sin(x):

$$I(x) = I_{\max}\left[\sin(2\pi x_w + \varphi_0)\right], \tag{9}$$

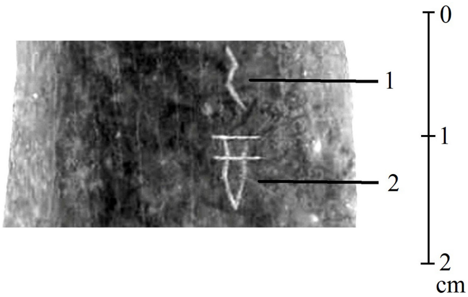

Figure 6. Jiaguwen with two numbered hieroglyphs (Chinese radicals (keys)): 1 is 乙 (2nd cyclic sign); 2 is 酒 (酉) (wine (key "wine", "vessel for wine"))

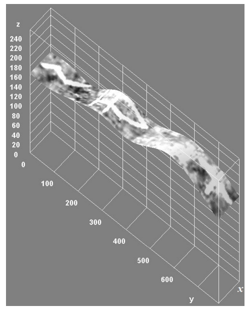

Figure 7. Digital 3D image of Jiaguwen (see Figure 6)

where $I_{\max}$ is a peak amplitude, $\pi \approx 3.14$, x_w is a dimensionless parameter, φ_0 is an initial phase.

We use different types of curves as fitting functions and not only the type given in equation (9). The research showed that the final profile under study is well characterized by adjustable functions of the sinusoidal (periodic) types, i.e. the functions that describe harmonic vibrations. This approach demonstrates additional possibilities for processing the received digital data. We plan to give a more detailed description in subsequent works. It can only be noted that such an approach can be promising in solving the problems of ancient hieroglyphs identification and certain automation of the research process.

The results obtained allow, in particular, to express the idea of using the series expansion of the obtained profiles in some basis functions, for example, like $\sin(x)$ and $\cos(x)$. So, we can use functions of periodic type not only as approximating functions in similar study, but also as the basis functions, i.e. as some orthogonal basis.

A comparison of Figure 1, Figure 3 and Figure 5 shows that profiles similar to those shown in the Figure 5, can be found in the Figure 3, for example, at the beginning, middle and the end of the profile. It is in those places that there are hieroglyphs containing elements similar to the hieroglyph "yué" (see Figure 4).

In the Figure 6 a part of the bone (scapula) presumably of a large horned animal is presented, on which written signs are depicted, recording the interpretation of fortune-telling or predictions [6].

The Figure 7 shows a digital 3D image of this Jiaguwen from Figure 6, obtained with the computer program "Fiji ImageJ" for Windows. The hieroglyphs are shown in Figure 7 as in Figure 6, from top to bottom and from left to right (along the vertical, i.e. y-axis in Figure 6, but slightly at an angle to the horizontal x-axis). Note that a section along the horizontal axis gives 2D profiles similar to those shown in the Figure 5 (after appropriate smoothing).

We emphasize that the computer program "Fiji ImageJ" for Windows allows you to export data in raster and vector formats. Then the digitized data can be processed in various graphic applications (for example, CorelDraw, etc.) that work, among others, with vector images. In conclusion, it is important to note that at a low noise level, it is possible to reliably identify a groove with a depth and width of at least 0.1 mm. It is unlikely that scribes used in antiquity (about 3–4 thousand years ago) finer tools for drawing hieroglyphs. Therefore, we can conclude that the described method of studying ancient artifacts makes it possible to obtain sufficiently reliable results that will undoubtedly be useful and promising in the study of ancient hieroglyphic signs. It should be emphasized that, in general, the error of the described research method at this stage does not exceed 20%.

For this study the following sources of illumination were used: natural (sunlight) light, household light sources ($\lambda = 0.5\ \mu$m), and LEDs (with illumination of 150–300 lux). Digital surface profiles were obtained using the "Fiji ImageJ" program for Windows [12, 16]. Computer processing of digital photometric data makes it possible to judge not only the different structural complexity of the test object and hieroglyphs under study, but also to determine their number and location [7, 12]. The processing of digital photometric data and the necessary calculations were carried out on the computer "Intel Pentium 4".

The methods proposed in our paper cannot completely replace the traditional research methods in linguistics, history and archeology; however, they undoubtedly allow us to look at current scientific problems from new, non-standard positions and obtain a number of innovative results. It should be noted that other approaches to the study of different kind of hieroglyphs have recently been developed (see e.g. [17, 18]). At the same time, it must be emphasized that the process of combining ancient Chinese hieroglyphic characters with modern digital systems is the significant milestone towards the popular and widespread use of this character system [19]. At the same time, it is obviously necessary to see the entire research process in broader historical, philosophical and cultural aspects [3–8, 19, 20]. In our opinion methods described in this article can be used for studying different symbol inscriptions like oldest hieroglyphs and cuneiform in various antique artifacts (bronze vessels, tortoise shells, stones, and clay tablets), for example: Chinese, Hittite, Akkadian, Sumerian, and Egyptian.

The possibilities of our innovative method can be expanded by using: a) ultraviolet and infrared light sources, including coherent radiation sources; b) various computer processing methods, both digitized images and the resulting digital surface profiles of the studied antique samples. The main advantages of the research method used are its non-contact, informative nature, and potentially sufficiently high resolution, which makes it possible to speak about its prospects in the study of such ancient artifacts.

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Новый метод корректной идентификации структурных элементов древних иероглифов

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Аннотация. В статье описан новый метод корректной идентификации различных структурных элементов древних иероглифов. Метод основан на фотометрии исследуемой поверхности древнего артефакта. Полученные данные преобразуются в цифровую форму с целью определения характеристик и параметров, характеризующих свойства исследуемой поверхности артефакта. Оцифрованные данные обрабатываются в различных графических приложениях, в том числе работающих с векторными изображениями. Проведено также несколько контрольных экспериментов. Полученные данные позволили однозначно обнаружить на поверхности артефакта древние иероглифы и определить их количество. Описанный метод изучения древних артефактов позволяет получить достаточно достоверные результаты, которые, несомненно, будут полезны и перспективны при изучении древних иероглифических знаков. Наш метод исследования характеризуется как: бесконтактный, информативный, чувствительный. Это свидетельствует о его важности и перспективности в исследовании подобных древних артефактов.

Ключевые слова: иероглифическая надпись, структурные элементы, поверхность, фотометрия, Цзягувэнь, Цзиньвэнь, китайские ключи, компьютерная обработка данных