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The Role of Ancient Written Signs in the Preservation and Development of the Chinese Language

Features of the Study and Analysis of Intricately Located Hieroglyphic Inscriptions Jiaguwen

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ABSTRACT

The article raises the question of the role and significance of ancient Chinese writing for the preservation and development of the Chinese language, the study of which is impossible without analyzing the monuments of writing and culture of China — Jiaguwen (writing on turtle shells and animal bones, XIV-XI centuries BC). The article raises the question of the need to search for new auxiliary research methods for such valuable and significant written monuments. The authors proposed and considered a statistical method for studying signs (keys / hieroglyphs) on turtle shells, thanks to which the possibility of a sufficiently accurate determination of the surface of the shell by digital photometry data was demonstrated. Thanks to this method, the number of characters (ancient keys / hieroglyphs) was determined in a number of complex areas. This method could be additional, primarily for visual research by specialists in various fields of science. The research of the ancient written language plays a vital role in understanding human history and enriching human civilization.

Keywords: *culture, ancient language, writing, linguistics, hieroglyphic inscription, Jiaguwen, turtle shell's surface, statistical characteristics and parameters, Chinese radicals (bùshǒu), complicated (entangled) hieroglyphs*

I. INTRODUCTION

The Chinese language, which is one of the oldest languages in the world, has its own specificity and is unthinkable without its writing, which served as the foundation for the formation of the Chinese language and ensured its preservation for several centuries of its existence.

The Chinese language has more than three thousand years of history and is one of two branches of the Sino-Tibetan family of languages. Initially, it was the language of the main ethnic group of China — the Han people (dominates the national composition of the PRC: more than 90% of the country's population). In its standard form, Chinese is the official language of the PRC and Taiwan, and one of the six official and working languages of the United Nations. The languages of the Sino-Tibetan family are spoken in China, Taiwan, and the countries of Southeast Asia; in addition, certain dialects of the Chinese language are the main languages of communication of the Chinese ethnic diasporas around the world. The Chinese language is a collection of very different dialects, and therefore is considered by most linguists as an independent linguistic branch, including separate, albeit related, linguistic and / or dialectal groups, united by a common script. The Chinese (Sinitic) family consists of several Chinese languages, often referred to as dialects.

The modern Mandarin Chinese language was artificially created in the middle of the 20th century. It is based on the vocabulary and grammar of "Mandarin" (Mandarin Chinese) and the Peking dialect - for pronunciation, i.e. the phonetics and vocabulary of Mandarin Chinese are based on the pronunciation norm of the Peking dialect, which

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belongs to the northern group of Chinese dialects. The Mandarin grammar corresponds to the norms enshrined in literary works in modern Chinese "baihua" (Báihuà / 白话), which are also closest to the northern dialects and inherited with certain changes the writing that came from the ancient Chinese language [1].

In the development of the Chinese language, three periods are usually distinguished - Ancient Chinese, Middle Chinese, and modern. In the history of the living oral language, the ancient Chinese period ends, most likely, around the 6th century AD, ancient Chinese language from the 5th century BC to the II century AD can be called classical, the language of earlier monuments - pre-classical, and the language of the III-VI centuries AD - late ancient Chinese [2].

By the beginning of the XX century the Chinese language turned out to be widespread throughout China, with the exception of some northern and north-western regions, where they spoke the languages of the Altai group, Thai and Mao-Yao [3]. However, by the beginning of the XXI century in the course of the implementation by the PRC government of the program for the dissemination of the official Chinese language Putonghua (Pǔtōnghuà / 普通话) throughout China, the Chinese language is gradually being introduced into those areas where it was historically not widespread [1].

In this article, we think it necessary to consider the writing of the Chinese language as the main connecting link between Ancient Chinese, Middle Chinese, and modern Chinese. From a political point of view, China is a very young state and its borders were formed only 2,000 years ago, despite the fact that the country's history goes back more than 5,000 years. The state united 56 officially recognized ethnic groups. It was writing that, over the centuries, glued together various ethnic groups on the territory of China, and also allowed, over time, to unite these ethnic groups into a single state with a language in which there are many dialects with a unified writing as the basis of the language.

Culturally and linguistically, China is characterized by a high level of diversification of languages / dialects (the question of considering whether these dialects are dialects or languages remain outside the boundaries of this study) within a single state. Each autonomous region, province, city, village speaks its own language or dialect, which may differ less if dialects developed side by side with each other, or more if we talk about northern dialects and dialects of the south.

With the exception of the northeastern part of the country, the borders of most of China's provinces were determined during the Yuan, Ming and Qing dynasties, i.e. from the XII century until the 20th century, when in China fell the monarchy. They were often carried out regardless of cultural, linguistic or geographic differences in order to prevent separatism and the rise of local military leaders typical of that period. In China, this difference between administrative and cultural boundaries is said to be "interspersed like the clenched teeth of a dog" (Quǎnyá jiāocuò 犬牙交错). Linguistic diversification also plays a huge role, the overcoming of which with the help of the spread of the common language, according to the plan of the authorities, should serve to unite the country.

The extremely high level of linguistic diversification is compensated by a single writing system and, to a certain extent, helps to smooth out the problem of the diversity of dialects. Overcoming this problem completely is on the agenda of the Chinese Communist Party. However, it is important to note that this issue is not only new for the country, but, moreover, has a long history and rich experience in finding approaches to solving the problem of developing and disseminating a single Chinese language, which would serve as a glue for the once independent parts of China, which have become a unified state relatively recently. From the moment when the separate principalities were united into the Qin Empire in 230-221 BC under the rule of Emperor Qin Shihuang, the idea of the need to create a single nation based on the national majority Han (hàn 汉) and a single state language that would cement the skeleton of the new empire - Hanyu (Hànyǔ 汉语) - that is, the language of the Han people soars over China. The first reform of hieroglyphic writing occurred in 213 BC, when Emperor Qin Shihuang, who unified China, eradicated local hieroglyphs used along with common Chinese in the kingdoms he conquered. He also ordered his entourage to compile new normative sets of hieroglyphs.

The oldest written monuments of the Chinese language are the inscriptions on the bones and turtle shells of Jiaguwen (甲骨文, XIV-XI centuries BC), which were used for fortune telling (XIII-XI centuries BC), as well as on bronze vessels (the earliest of them date back to the end of the 2nd millennium BC), although Sinologists have certain doubts about these dates [2].

The Jiaguwen writings are hieroglyphic inscriptions that record the results of fortune-telling or predictions [4], [7], [8], [9], [10]. They are unique in their own way. These objects are often poorly preserved, but are objects of great historical, cultural and scientific value. Basically, their research is devoted to the study of hieroglyphic inscriptions applied to them with the aim of interpreting their content, as well as identifying ancient keys (hieroglyphs) [4], [7], [8], [9], [10].

Due to the immense historical and cultural value of Jiaguwen, their poor preservation and fragility, there are certain difficulties in accessing and studying them at the storage site of these artifacts. Jiaguwen are priceless treasures of the PRC that can tell a lot about the history, traditions, customs, culture, religion and everyday life of China. Access to such valuable artifacts is possible only in some museum exhibits and mostly only for visual inspection. However, for full-fledged research, textual experts, archaeologists, linguists, sinologists and ethnographers often need to get closer to the object of study, have unlimited access to it, subject it to tools for better analysis, which is impossible with Jiaguwen for the above reasons.

In this article, we would like to consider a new statistical research method, which can be a good addition to the traditional methods (mainly visual) used nowadays [4, 7–10]. This method allows using digital data from photometry of the surface of the shell to determine various statistical characteristics and parameters characterizing the properties of the investigated surface [11], [12]. The main advantages of our research method are its contactlessness, non-destructiveness, informational content, potentially high enough resolution, for example, in terms of the statistical parameters of the surface profile, which makes it possible to speak of its promise in the study of such ancient examples of art and culture as Jiaguwen.

The main goal at this stage of the work is to demonstrate the possibility of correct identification of ancient hieroglyphs (keys), applied in an irregular manner on the surface of the tortoise shell, according to the obtained digital profiles of the surface of the sample under study. The results obtained can be useful in mathematical linguistics, lexicostatistics and sociolinguistics, especially in the statistical analysis of similar hieroglyphic inscriptions.

II. RESEARCH OBJECT AND METHOD. RESULTS AND DISCUSSION

The object under study is the shell of an ancient turtle (XIV-XI centuries BC), on the surface[1] of which hieroglyphic inscriptions Jiaguwen were depicted (see photo in "Fig. 1"). The subject of research is the surface of the shell with the ancient hieroglyphs depicted on it.

In this work, the main attention is paid to the study of the possibility of finding the position of the profile section where the scanning line passes from one column of hieroglyphs to the adjacent column due to the fact that they are both located at a certain angle to the vertical, i.e. jumbled. This task is part of a complex inverse problem for pattern recognition, namely: identification of ancient hieroglyphs applied to the surface of a turtle's shell. Solving this important problem will avoid mistakes at the initial stage, when, according to the obtained digital profiles of the surface of the test sample, approximating (fitting) autocorrelation functions (ACF) are found. Recall that our method is based on photometry of surface profiles, in which a sample of brightness levels in a discrete set of points is carried out with subsequent conversion to digital form [11], [12], [13].

In this work, a statistical research method was used, which makes it possible to find the statistical characteristics and parameters of the profiles of the studied sample, i.e. tortoise shell (see details in [11], [12]). The most important statistical characteristic of an uneven surface is the autocorrelation function, which characterizes the relationship between the analyzed function and its shifted copy of the argument shift value. The most important statistical parameters of the surface irregularities are: standard deviation σ and the correlation radius (interval) r. The standard deviation characterizes the amount of dispersion of the values of a random variable relative to its mathematical expectation, i.e. mean value. A larger value of the standard deviation shows a greater spread of values in the given set of values, while a smaller value indicates that the values in this set are grouped around the mean. The correlation radius determines the characteristic size of the "particles" of the scatterers on the surface of the object under study. These particles should not be taken literally. This term is used to indicate the area within which the correlation takes place (the area of "distortion" of the surface). On the studied object, such characteristic "distortions" of the surface are hieroglyphic signs.

[1] The approximate dimensions of the investigated surface of the shell: width 160 mm, height 190 mm.

Fig. 1. Jiaguwen example (甲骨文 is "writing on turtle shells") – hieroglyphic inscriptions fixing the results of fortune telling or predictions. Explanations for the photo are given in the text.

Let us present formulas that determine the form of the two most well-known autocorrelation functions in statistics: exponential and Gaussian [11], [12].

The exponential autocorrelation function is described by the following formula:

$R(y) = \sigma^2 \exp[-|y/r|]$. (1)

The Gaussian autocorrelation function is described by the formula:

$R(y) = \sigma^2 \exp[-(y/r)^2]$. (2)

In (1) and (2), the variable y is the coordinate along which the photometry of the surface profile of the test sample is performed. In our studies, scanning was carried out along both coordinates of the investigated flat surface of the sample (see "Fig. 1"): horizontal x and vertical y; but the results are presented only for the case of photometry of the surface along the coordinate y.

"Fig. 2" shows an adjustable Gaussian function R of the form (2), which approximates the experimental ACF and characterizes, respectively, the surface profile along the vertical line marked with the numbers "1" in "Fig. 1" (hereinafter: line "1-1"). The numbers "2" in "Fig. 1", a horizontal line is marked (hereinafter: line "2-2", where $y \approx$ 950-1000 arb. units)), at the intersection of which with the line "1-1" there is an area (marked with an ellipse "3"), where the line "1-1" passes from the left vertical column of hieroglyphs to the adjacent right vertical column (approximately at the interval $y \approx$ 800–1200 arb. units). Earlier, we showed that the surface of a shell with hieroglyphs is better described by the Gaussian autocorrelation function [11], therefore, in this work; preference was given to this approximating ACF. It should be noted that in the study, the most common in the statistical analysis of the surface were considered as fitting functions: exponential (see (1)), Gaussian (see (2)), as well as the type of damped cosine and logistic.

Note that the profile of a surface without hieroglyphs when using a fitting exponential correlation function is characterized by the following parameters: standard deviation $\sigma \approx 10$ µm (determination error no more than 3%) and correlation radius $r \approx 27$ mm (determination error no more than 5%) [11]. In this case: a) the size of irregularities in the plane (lateral) of the object under study varies approximately in the interval from 1–2 mm (close to the average value of the step of irregularities S initial profile: S = 3 mm) up to 20–30 mm; b) the size of the irregularities in height h (vertical) varies approximately in the range from 5 µm (roughness) to 2 mm (solitary irregularities of the groove type).

For the fitting Gaussian correlation function (see "Fig. 2"), the corresponding statistical parameters were determined: the root-mean-square deviation σ and the correlation radius r of the roughness of the shell surface profile: $\sigma \approx 15$ µm (determination error is no more than 3%), $r \approx 3$ mm (determination error is no more than 5%).

To find the position of the section of the profile, where the vertical scanning line passes from one column of hieroglyphs to the adjacent column, it is proposed to conduct a comprehensive study of the properties of the Gaussian approximating ACF (see "Fig. 2").

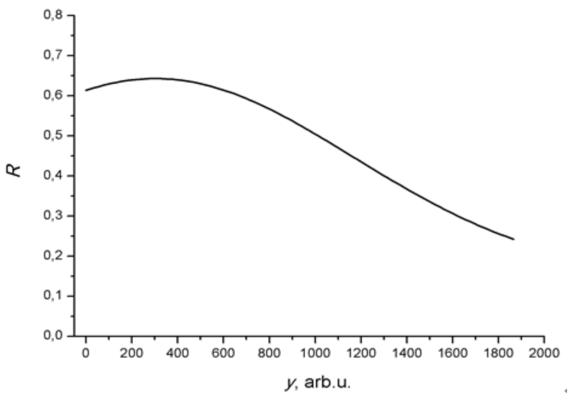

Fig. 2. Normalized Gaussian fitting autocorrelation function.

For this purpose, let us first find the form of the approximating autocorrelation functions $R(y)$ [8], [9] for the surface area with hieroglyphs containing the line "1-1".

"Fig. 2" shows the form of one of the possible adjustable normalized Gaussian ACFs, which we will use in our further analysis. Briefly, the essence of the approach is based on the study of the behavior of both the fitting ACF itself and on the study of the behavior of its first and second derivatives. In particular, the location of extrema (zeros, minimums and maxima) of these functions is investigated.

<u>The first method</u> to find the position of the surface profile section, where the vertical scanning line passes from one column of hieroglyphs to an adjacent column, is based on the study of the fitting Gaussian ACF $R(y)$ and finding the inflection point of the function $R(y)$. Its essence is clear from the following presentation.

Let us take the maximum value of the ordinate to the left and the minimum to the right of the center (approximately in the interval of $y \approx 800$–1200 arb. units) of the Gaussian ACF $R(y)$ on the graph in "Fig. 2".

Using these values, we find their approximate difference: 0.64 - 0.24 = 0.4 arb. units. Let's find the average: 0.24: 2 = 0.12 arb. units. Now we find the location of the point with the ordinate in the middle, between the above values: 0.4 + 0.12 = 0.52 arb. units. We draw a vertical line from the ordinate with this value to the intersection with the abscissa axis, we obtain the value $y = 950$ arb. units, where the inflection point of the function $R(y)$ can be. Let us now look at the "Fig. 1", we see that it is in the vicinity of this point (in the center of the ellipse "3" in "Fig. 1") that there is a surface area where there are no hieroglyphs on the vertical line passing from the left column of characters to the adjacent right column.

A preliminary analysis showed that in the vicinity of this point ($y \approx 950$ arb. units) there may be an inflection point of $R(y)$. Note that the vertical (maximum) linear size of the area bounded by ellipse "3" is approximately 100 : 1600 = 0.063, i.e. does not exceed 1/16 part (about 6% or 108 arb. units) of the length of the vertical scanning line. Thus, the error in determining the position of the center of the desired area bounded by ellipse "3" does not exceed ± 3% (i.e., ± 54 arb. units).

The second method of finding the section of the profile, where the scanning line passes from one column of hieroglyphs to the neighboring one, is based on the study of the first derivative for the approximating Gaussian ACF. It is known that a necessary condition for the existence of a (local) extremum of a differentiable function $R(y)$ is the equality to zero of its first derivative: $dR/dy = 0$. Sufficient conditions for the existence of an extremum: $dR/dy = 0$, $dR/dy > 0$ (minimum) or $dR/dy < 0$ (maximum). Moreover, the function $R(y)$ under consideration has an inflection point at a given point if and only if its first derivative dR/dy has a local extremum at this point.

It is seen in the "Fig. 2" that in the vicinity of a possible inflection point ($y \approx 950$ arb.u.) the first derivative has, on the one hand, extrema: $dR/dy \to 0$, $dR/dy \to$ min. On the other hand, on this interval $dR/dy < 0$, i.e. a (negative) maximum is observed at this inflection point.

Thus, it has been established that, indeed, in the vicinity of this point $y \approx 950$ arb. units is the inflection point of the curve $R(y)$. Analysis of "Fig. 1" showed that the vertical scanning line (line "1-1") passes from the left column of hieroglyphs to the adjacent right column approximately in the center of the ellipse "3".

The third method of finding the section of the profile where the scanning line passes from one column of hieroglyphs to the neighboring one is based on the study of the second derivative for the approximating Gaussian ACF. A necessary condition for the existence of an inflection point of a twice differentiable function $R(y)$ is the equality to zero of its second derivative: $d^2R/dy^2 = 0$. A sufficient condition for the existence of an inflection point of a differentiable function $R(y)$ is the equality to zero at a given point, for example, its first and second derivatives, and the third derivative d^3R/dy^3 there is not equal to zero.

It can be seen that in the vicinity of the assumed inflection point ($y \approx 950$ arb. units), the second derivative actually tends to zero with an accuracy of up to six decimal places (in this case, the function under consideration has a local minimum there: $d^2R/dy^2 \to$ min). Indeed, the extremum of the second derivative ($d^2R/dy^2 = 0$) are on the line segment "1-1" (with ordinates $y \approx 950$-1050 arb. units (or point $y \approx 1000$ arb. units): $d^2R/dy^2 \to$ min; moreover $d^2R/dy^2 < 0$. In this case, the third derivative (in accordance with the sufficient condition for the existence of an inflection point) d^3R/dy^3 in the vicinity of this point ($y \approx 950$ arb. units) is not equal to zero. A more detailed analysis with the presentation of the corresponding graphs will be given in one of our next papers in the field of mathematical linguistics.

III. Estimation of the Number of Ancient Hieroglyphs or Chinese Radicals (部首 / Bùshǒu)

To determine the number of Chinese radicals (ancient hieroglyphs) N, we divide the length L of the scanning interval of the surface profile by the correlation radius r, characterizing the profile statistics [11].

Indeed, the correlation radius determines the characteristic size of the "particles" of the scatterers on the surface of the investigated object. This term is used to refer to an area of a surface with a "distorted" ("disturbed") roughness. In our case, this surface distortion is mainly created by keys (Chinese radicals); therefore, the rather simple estimate of the value N proposed by us is quite fair. The approximate average length of the scan line of the shell surface profile: $L = 16$ cm.

Let's find the number of keys (ancient hieroglyphs) on the scanning line (line "1-1") containing the hieroglyphs, according to the following formula [11]:

$$N = L/r. \quad (3)$$

Since we are using a statistical approach, following [11], find the average value of the effective correlation radius based on two estimates of the correlation radii – for the shell surface profiles without keys (hieroglyphs) and with keys: $r = [(27 + 3)/2]$ mm = 15 mm.

Now let's determine the number of keys in accordance with the formula (3): $N = 160/15 \approx 11$. So, the approximate number of Chinese radicals (ancient hieroglyphs) $N = 11$. According to our calculations, there are 12 hieroglyphs on the line "1-1" (see the photo in "Fig. 1"). Thus, the obtained radical's value N differs from the exact one by 1, i.e. the error in finding the number of keys is ≈ 9%. At this stage of research, such an error can be considered good. Thus, this work goal was also successfully achieved.

Now let's take into account the location of the inflection point on the photometric line, i.e. section of the profile where the scanning line passes from one column of hieroglyphs to the adjacent column due to the fact that they are both located at a certain angle to the vertical (see "Fig. 1"). As it was established above, the error of finding the location of the inflection point (located inside the ellipse "3", "Fig. 1") is less 6%, which allows to unambiguously separating the left and right columns of hieroglyphs inside the ellipse "3", where they are crossed by the scanning line "1-1". As a result, it is possible to quite accurately determine how many hieroglyphs from the found number of keys N are in the left column: 5. Then the number of hieroglyphs N in the right column: $11 – 5 = 6$. As seen from "Fig. 1", the left column actually contains 5 hieroglyphs. And in their right, in our opinion, 7, i.e. possible error is exactly 1 hieroglyph. It should be noted that the accuracy of determining the number of hieroglyphs in the right column could be influenced by the fact that the scanning line "1-1" immediately under the ellipse "3" only touches the first hieroglyph below. As a result, its contribution to the photometric data was less than that of other hieroglyphs due to the influence of interference created by the surface relief without hieroglyphs. Analysis of the problem of pattern recognition in the presence of interference is beyond the scope of this article.

More detailed mathematical and computational analysis will be given in one of our next papers in the field of mathematical linguistics concerning Chinese language and writing as well as Jiaguwen (甲骨文).

IV. Conclusion

In this article, the authors have shown the role and significance of the ancient Chinese writing system for the preservation and development of the Chinese language, its unification and the unification of the Chinese nation, to illustrate the antiquity of Chinese writing the well-known monuments of the language and culture of China — Jiaguwen (writing on turtle shells), which date back to the XIV-XI centuries BC, were described and studied.

The question was raised about the importance of conducting a study of the ancient writing of China, which served as the basis for the preservation and development of the Chinese language and the formation of the Chinese nation.

Considering that the oldest samples of Jiaguwen (甲骨文) under study are often poorly preserved, as well as of high historical, cultural and scientific value, our research method can be a good addition to the traditional methods (mainly visual) of research used now.

The article proposes and discusses a new statistical method for studying written signs (keys and / or ancient hieroglyphs) on turtle shells. As a result, the possibility of sufficiently accurate determination of the position of the profile section, where the scanning line passes from one column of keys (hieroglyphs) to an adjacent column of keys, based on digital photometric data of the carapace surface, was demonstrated, due to the fact that they are both located at a certain angle to the vertical. The error of this method at this stage of research does not exceed 6% on average. In addition, according to the digital data of photometry of the surface of the shell, the number of keys (ancient hieroglyphs, Chinese radicals / 部首 / bùshǒu) was determined for this difficult case, when two adjacent columns with hieroglyphs intersect. The determination error does not exceed 9%. It is obvious that the achieved accuracy of solving the problems posed in the work is undoubtedly good.

The method allows, in principle, to automate the process of statistical processing of ancient texts of the Jiaguwen type. This makes it possible to speak of its promise in the study of such ancient examples of art, culture and science as Jiaguwen, which often exist in single copies and often have poor preservation, when visual identification of hieroglyphic inscriptions is difficult, and individual elements of the inscriptions are poorly visible or almost indistinguishable.

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