

Automation of Fishhooks Objective Measures

S. Chabrier, G. Molle, E. Conte, and C. Carlier

Abstract—Fishing has always been an essential component of the Polynesians' life. Fishhooks, mostly in pearl shell, found during archaeological excavations are the artifacts related to this activity the most numerous. Thanks to them, we try to reconstruct the ancient techniques of resources exploitation, inside the lagoons and offshore. They can also be used as chronological and cultural indicators. The shapes and dimensions of these artifacts allow comparisons and classifications used in both functional approach and chrono-cultural perspective. Hence it is very important for the ethno-archaeologists to dispose of reliable methods and standardized measurement of these artifacts. Such a reliable objective and standardized method have been previously proposed. But this method cannot be envisaged manually because of the very important time required to measure each fishhook manually and the quantity of fishhooks to measure (many hundreds). We propose in this paper a detailed acquisition protocol of fishhooks and an automation of every step of this method. We also provide some experimental results obtained on the fishhooks coming from three archaeological excavations sites.

Keywords—Automated measures, extraction, fishhook, segmentation.

I. INTRODUCTION

ARCHEOLOGICAL excavations in Eastern Polynesia has revealed fishhooks as central in reconstructing the Polynesian past history. In Eastern Polynesia, archeologists have used fishhooks recovered from archaeological excavations as chrono-cultural indicators. These fishhooks are considered crucial in retracing fishing techniques, which represent a significant characteristic of ancient Polynesian life.

In order to draw conclusions about the fishing techniques used by ancient Polynesians, it is first necessary to classify the fishhooks found in archaeological excavations, and take morphometric measurements. These morphometric measurements are usually manually taken: they are really long to perform and inaccurate because of the human factor.

The main purpose of this paper is to propose method to automate and speed up these morphometric measures in an objective way. To achieve this goal we need to set a protocol for image acquisition of these fishhooks and the adaptation of a manual objective method [1]. This study is the first necessary step of a bigger method that is being studied for the

classification, rebuilding and measurement of all fishhooks found whether whole or not.

In the first section we present the importance of fishhooks for Polynesian ethno-archaeology while in the second one we introduce the new objective measuring approach used nowadays for the Polynesian fishhooks. In the third section we develop the automatic method proposed, and in the fourth section we expose some experimental results of this new method and explain them. Last we conclude this study.

II. IMPORTANCE OF FISHHOOKS FOR POLYNESIAN ETHNO-ARCHAEOLOGY

Archaeologists have always been on the lookout for various artifacts that could be considered as cultural and chronological markers to identify the trends and changes of ancient societies. Concerning the Oceanic cultures of the Pacific, the fishhooks were playing an important role in the technical tool set, especially for the ancient Polynesians. As the marine resources were a fundamental part of their diet, they were first of all skilled fishermen. That is how they developed many techniques and devices using natural material that the remote islands could have offered them. Among those is the oyster pearl-shell (*Pinctada margaritifera*) in which were made the majority of the fishhooks. Archaeologists discovered a quantity of them in the excavations that cover a long period of time since the first human settlements around the end of the first millennium A.D. until the Western contact. The manufacturing also continued until the beginning of the 20th century in some isolated archipelagos as Tuamotu.

The study of fishhooks is of great importance for a better understanding of traditional fishing which was an essential aspect of the daily life of Polynesians. In the favorable context of Central-East Polynesia, the development of ethno-archaeological studies offers to relate the type of fishhook to a fishing strategy and a prey ([2], [3]). Comparing this data allows us to reconstitute an entire subsistence system. The first step of this complex analysis is to build typologies of these artifacts by taking some precise measures on objects which, unfortunately, are not often complete but rather fragmented.

III. A NEW APPROACH IN MEASURING THE POLYNESIAN FISHHOOKS

A. Old Measuring Methods

Since the first archaeological discoveries in Polynesia, the specialists have developed different ways to measure the fishhooks, leading to a multiplicity of approaches and results. In addition to the pioneer works of Emory, Bonk and Sinoto in Hawaii (1959) [4], Suggs in Marquesas (1961) [5] and

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Garanger for a general Oceania revision (1965) [6], we can also highlight the studies of Allen (1996) [7] and Ottino (1992) [8] on some Marquesan sites.

Two main problems appear when we take an interest in these several methods. First, we must admit a certain part of subjectivity depending on the way we place the artifacts. Most of the archaeologists chose to position the fishhooks on a vertical axis and perpendicularly to the bend. If this method gave good results for simple artifacts like jabbing hooks, it did not fit with the more elaborated shapes as rotating hooks with curved or angled shanks. For these forms, the measuring could provide very different results following the main orientation of the object. Secondly, the human factor has to be also taken into account as two persons could obtain different measures on the same item. In this case, it is more the precision of the measure that varies from a specialist to another, inducing a sizeable margin error.

B. A New Objective Method

Recently, a new method was proposed to measure the fishhooks in a more objective and rational way [1]. The advantage is that it could be used for each fishhook shape or type, whoever is the author of the measures. It consists in defining two reference points on a x/y grid on an enlarged photograph of the fishhook to study. The interior angle of the head must be placed on the 0 origin with the point tip of the fishhook on the x axis (Fig. 1-(a)). In this way, we have a standardized position of the object which permits to draw the tangent to the bend (Fig. 1-(b)) and perpendicular lines that frame the fishhook (Fig. 1-(c)). In the end, we are able to take five essential measures (Fig. 2) which are the length of the shank, the length of the bend, the length of the point leg, the gap between the shank and the point tip and finally the depth of the fishhook.

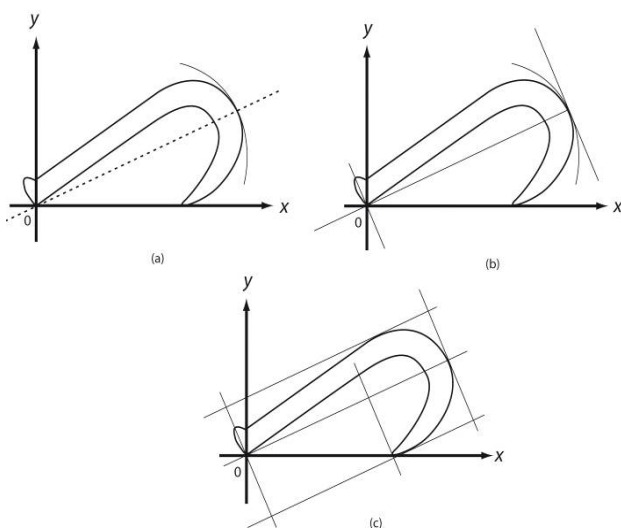


Fig. 1 New measurement method steps

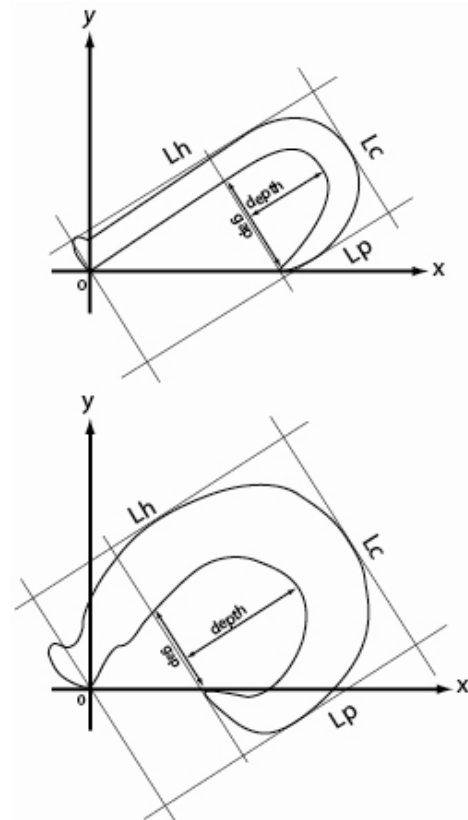


Fig. 2 New objective method's five measures on two different fishhook types

This new method was successfully applied to a large archaeological collection of fishhooks recovered in Manihina dune site excavations, on the island of Ua Huka located in the northern group of the Marquesas archipelago, French Polynesia [9]. This study has established the benefit of the standardized position for determining reference points.

Of course, one of the advantages of the method is the simple application to any collections in Oceania. In the present case, the ethno-archaeological approach we want to develop on Ua Huka Island needs to study different collections. Three sites are currently retaining our attention: Manihina, Hane [10] and Hatuana [11] that provided hundreds of pieces. It is not conceivable to manually apply this method to a corpus so large. For this reason, we decided to develop a computational tool for measuring automatically the fishhooks through a capture data. This automated method is explained in the next section of this article.

IV. AUTOMATION OF THE MEASUREMENT

To automate the objective measuring method presented in [1], it is necessary to define a complete image processing chain. Some steps are more critical than others because they can cause larger variations in the results.

The first step in the automated image processing chain is of course the acquisition of an image of the fishhook we need to measure. Under certain conditions, this step can facilitate the following one which consists in extracting the objects of interest: the fishhook and the ruler to determine the scale.

Once they are extracted, we can begin to apply the objective measurement method. The key point of this method lies in choosing the first two points for the head of the fishhook and the point tip. A positioning error in one of them could significantly influence the measurement result. Finally, once these two points are extracted, we can compute the rest of the lines and resulting points.

A. Step 1: Acquisition Protocol

One problem with measurements performed by the experts is the bias caused by the inclination of the view from the fishhook. The look is never exactly perpendicular to the plane in which it resides. To avoid this, it is necessary to use a chassis acquisition camera to keep it at a given height and at a given angle in relation to the object being photographed. In addition, the fishhooks to be photographed are made of oyster pearl-shell which reflects a lot the light, so it is almost impossible to use the camera flash. It is then necessary that the bench has indirect lighting avoiding glare and minimizing shadows. We then chose to use the acquisition bench Kaiser 5304 which has 2 fluorescent lights of 18W and is easily transportable for museums acquisitions for example.

Regarding the camera, it is not necessary to take the most advanced possible. Indeed, with a mid-range model we get already from 10MPx an accuracy of about the thirtieth of a millimeter, which is already more than necessary because the precision required for the ethno-archaeologists does not exceed a tenth of mm. We therefore opted for a Sony bridge type camera of 10 MPx.

The next point determines the ease and the accuracy of the extraction of the fishhooks for the next step. This is the choice of this background behind the fishhooks. The difficulty of extracting the fishhooks in the acquired images rely on the fact that their main composition is the pearl shell, but also on the fact that this shell may be damaged, which can give a very significant range of different colors and so a complex texture. In addition, some information can be written with a felt pen on some fishhooks. The idea is then to use a background color the more remarkable possible in order to extract in the better way the fishhooks.

Thus, in order to have a generic method, it is necessary to determine an image area where there is only background and no object. In this area, we can then compute statistics to facilitate the subsequent extraction of the fishhook. After extensive testing, we noticed that the funds made up of extreme values in the different layers allowed better detection of objects that backgrounds with intermediate colors. You may notice the difference of extraction of a fishhook according to the background color in the Fig. 3. This figure shows only a few representative sample of background colors we have tested.



Fig. 3 Fishhook extraction sample according to the background color

The last point to consider in the acquisition protocol relates to a way to determine its own scale. To overcome this problem, we opted for the presence of a measuring ruler on the photo. So we opted for the positioning of the items following a precise pattern as presented in Fig. 4. To the left of the photo must be the scale, then we let an empty space roughly equivalent to two times the width of the measuring scale, and finally the fishhook can be positioned with the shank vertically.

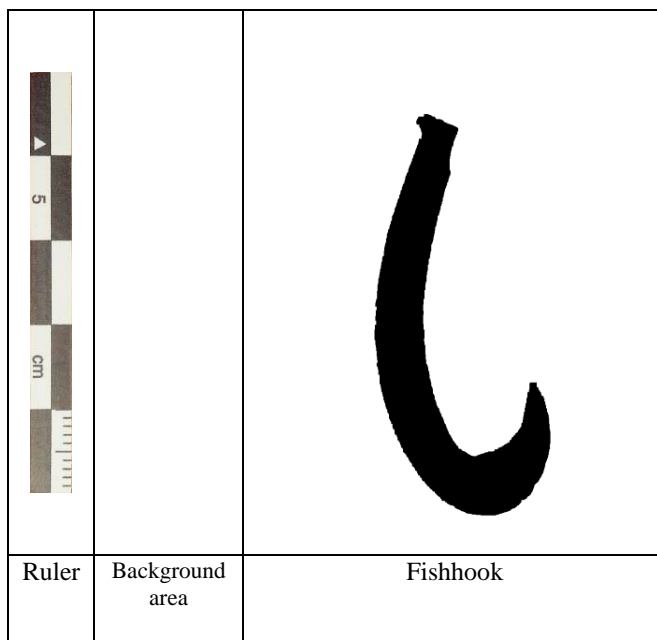


Fig. 4 Acquisition pattern

B. Step 2: Ruler & Fishhooks Extraction

For this step, we have to extract the objects in the foreground from the background. Usually, when we have a complex background, the best way to extract an object from it is to use a temporal acquisition and to compute it from the successive frames. One can find a review of some of such methods in [12].

In our case, we cannot have a temporal acquisition, which is why it is necessary to have a background most easily extractible. The methods used to perform this extraction are segmentation ones. There are two main types of image segmentation: methods which consists in extracting the edges of the objects and methods which consists in extracting classes (general case of region extraction).

The edge detection segmentation methods are inappropriate here because of the textured nature of fishhooks and because of the shadows that we can't eliminate during the acquisition.

The classification methods are here more appropriated since they can deal with textured areas. These classification methods can be supervised or unsupervised.

The problem with the unsupervised ones such as FCM [13] [14] is that, even if we give the right quantity of classes to find, fishhooks will result in more than a single class because of the complexity of their textures. More than that, in the supervised case the fishhooks textures are so different from one to another that it would be unthinkable to have enough of each kind to learn correctly their texture. The idea here is then to use a simple classification method such as k-means [15] that don't need too much learning data to detect the background and the other objects. In this case, finding only some area of interest in the picture to compute can be enough.

We can then use the acquisition pattern to know where to get some pixels from each of the two classes we want to detect: the ruler and the fishhook (the objects) and the background. For the ruler and the fishhook, we can do a basic binarisation according to the mean and standard deviation of the background area with an empirically determined additive threshold of 40 for each channel to be able to get nearly the whole objects because of the noise of the pictures. Once we get approximately these two items, we can close them and then erode them to be sure we get only pixels that belongs to them. At this point we can get a subset these two set of points for the k-means learning, and the points of the background area from the acquisition pattern to finish the learning.

We used the L^*a^*b color space for the K-Means clustering [16]. The $L^*a^*b^*$ space consists of a luminosity layer ' L^* ', chromaticity-layer ' a^* ' indicating where color falls along the red-green axis, and chromaticity-layer ' b^* ' indicating where the color falls along the blue-yellow axis. All of the color information is in the ' a^* ' and ' b^* ' layers. We can measure the difference between two colors using the Euclidean distance metric. A problem encountered here is the precision of the outline on the segmentation result of the fishhook.

Regardless of the background used, because of the pearl shell which composes the fishhooks, the background color always reflects slightly the whole circumference of the fishhook making the segmentation result inaccurate. It is then necessary to introduce a threshold distance added to the distance ' a^* ' ' b^* ' to improve the fishhook detection. To determine the best threshold value to add, we computed the segmentation result of all the fishhooks from the database by adding a threshold from 1 to 20 to the detection distance of fishhooks. Then an expert has determined for each hook the optimal additional threshold. This threshold ranges between 10 and 14 with an average of 12.15, we then chose to take this value as the additional threshold to the detection distance of fishhooks.

The Fig. 5 presents 3 samples of fishhooks extraction using the k-means method over a black background.



Fig. 5 Fishhook extraction using k-means method

The ruler is extracted the same way and is simply closed to erase the marks on it. Next we can compute the vertical distance between the white bars of the ruler. Because of the discrete nature of the picture, we can have a slightly variation of these distances, so we can take their mean value to get the more objective picture scale.

C. Step 3: Determination of the Two First Key Points

The objective measuring method defined in [1] proposes to measure five remarkable lengths through the plot of seven lines and their intersections. All of these lines has a position completely conditioned by the two starting points chosen: the head point and the point tip.

The head point corresponds to a rest point of the fishhook on a surface. The point tip is the tip of the other end of the fishhook. Due to the acquisition precision, a pixel has an accuracy of about the fortieth of a millimeter. This is the reason why the head point and the tip point are rarely represented by a single point. These ends are often eroded and rounded or even slightly flattened and this is the case even on fishhooks considered "perfect" and not broken.

Let consider that the fishhook is well positioned according to the acquisition protocol previously defined with the shank upward. Let also consider that the point tip is to the right. If it is on the left, it will then suffice to do a vertical symmetry of it. Last, let consider that we have extracted the fishhook into a binary image BW where the background is *false* and the fishhook *true*.

There are nine types of fishhook shapes to be measured. Fig. 6 shows an example of some of them.

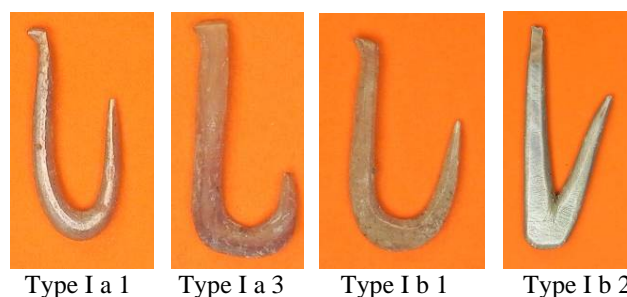




Fig. 6 Different types of fishhooks available

The protocol we have then defined to detect the two basis key points (the point tip and head) must work on the nine shape types and can be resumed to the following three steps:

Step N°1:

This step consists in finding the rest line of the fishhook as if we had to place it on a plane onto the head and the tip. Fig. 7 provides two examples of such a line for two important types of fishhooks.

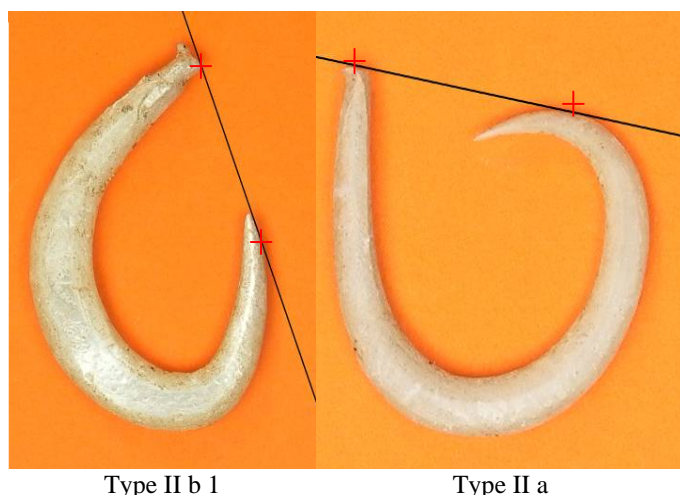


Fig. 7 Two samples of step 1 results of the method to detect the head and the point tip

The algorithm used to find the support line of this step is the following one:

1. computation of the inner outline of the fishhook (*BW_outline*) obtained by subtracting the erosion of *BW* using a 3x3 window to *BW*.
2. determination of the highest point of the fishhook which will be used to find the head support point.
3. selection of all the points of *BW_outline* within a range of a fifth of the width of the fishhook into *BW_outline_head*.
4. search for the line having the smallest intersection with *BW*. This line's features are computed according to two support points: one from *BW_outline_head* and the other from *BW_outline - BW_outline_head*. Another condition is required for getting the proper line: the slope coefficient of the line must be positive.

If we don't use this condition, we could have a support line resting on the shank.

The fourth part of this algorithm is rather long to compute according to the size of the fishhook and the picture resolution. According to the fishhooks we are measuring in this study, the outlines can have from 1500 points to more than 200'000 points, and they generally have nearly 4000 points for fishhooks 1.3cm in height... We noticed that the support points of the set of lines seemed to be remarkable points (points of interest). Then we used the Harris method [17] to search for points of interest from *BW*. We used these points instead of *BW_outline* (less than 400 in the worst case), and it turns out that the support points and the line found are exactly the same as with the method browsing the whole outline. The difference relies on the low computation time with a gain that can exceed two hundred times...

Once we found the support line with its two points, we keep the point located at the level of the head for the next step.

Step N°2:

The main objective of this step is to find the point tip of the fishhook. We must deal here with two different cases: in most cases the point tip points upward, but in the case of type IIa fishhooks, the tip can be directed to the left or down. We have then first to find if we are in front of a fishhook of type IIa. To do this, we apply a first algorithm:

1. computation of all the lines passing through the support point from the head found in the previous step, and passing through a point of *BW_outline* close to the second support point found in the previous step. The threshold distance used to find this second point is one fourth of the width of the fishhook.
2. for each of these lines, we perform an intersection with *BW* and then a conditional labeling of this intersection allowing to count the quantity of areas on the current line. This line is supposed to contain either two contiguous areas corresponding to the head and the point tip, or 3 areas corresponding to the head point, the point tip and the support of the whole tip. However, due to the discrete nature of the image sometimes we have more contiguous areas than reality. It is therefore necessary to consolidate some of these areas when they are too close according to a distance threshold. We empirically determined its value.
3. If the maximum amount of labeled areas present on these lines is two, then we are in the general case, but if it is 3, then we are in the case of a fishhook of type IIa.

Thus, in the general case the point tip happens to be the highest point from *BW* in a neighborhood close to the support point tip found in the previous step. If several points have the same maximum height, they are necessarily contiguous, and it is sufficient to take the central pixel among them.

In the case of a fishhook of type IIa, we seek the line resulting in the minimal intersection of the conditional labelisation for only the two first areas, which corresponds to the areas from head and point tip. We thus obtain a point for

the second area nearly corresponding to the point tip. Then we search in an area very close to this point in BW if there are no local ordinate minima to be found. As well as for the previous case, if there are several pixels found, they are necessarily contiguous, and it suffices to take the central one. The point found corresponds then to the point tip.

Fig. 8 provides two examples of such line and point tip for two important types of fishhooks.

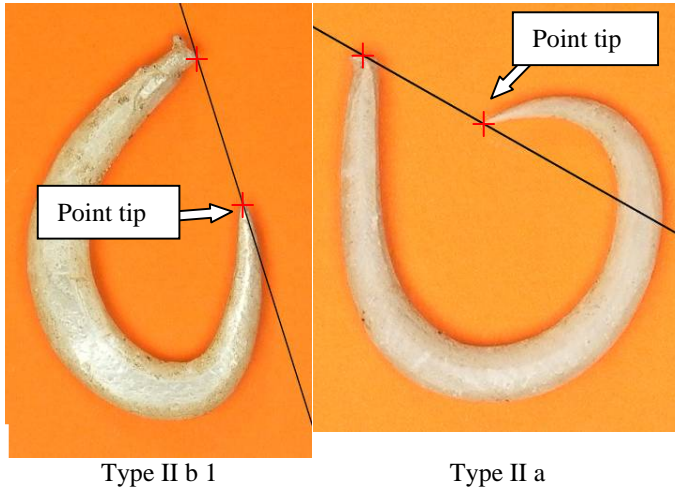


Fig. 8 Two samples of step 2 results of the method to detect the head and the point tip

Step N°3:

Once the point tip found in step 2, the inclination of the line passing through this point and the head point from the step 1 may have changed and therefore cut off the head instead of lying on it. We then set the point tip to the position found in step 2 and search in a local neighborhood near the point from head the final point that allows the smallest intersection between the new line and the head of the fishhook.

Fig. 9 provides the lines from the step 2 and 3 for a given fishhook.

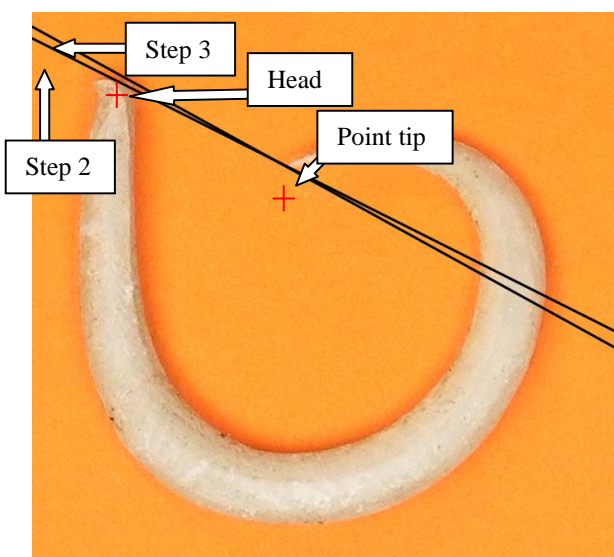


Fig. 9 Samples of step 3 result compared to its sample 2 result of the method to detect the head and the point tip

D. Step 4: The Other Points

Once the two key points found (HeadPt and TipPt), we can apply the manual method which is summarized below:

- $Pt1$ is the farthest point from $HeadPt$ of $BW_outline$,
- computation of the equation of the line passing through points $HeadPt$ and $Pt1$: $Line1$,
- computation of the equation of the line perpendicular to $Line1$ and passing through the support point $Pt1$: $Line2$,
- computation of the equation of the line perpendicular to $Line1$ and passing through the support point $HeadPt$: $Line3$,
- computation of the equation of the last line parallel to $Line1$ the more to the left going through one or more points of BW : $Line4$,
- computation of the equation of the last line parallel to $Line1$ the more to the right going through one or more points of BW : $Line5$,
- Computation of the equation of the line perpendicular to $Line1$ and passing through the support point $TipPt$: $Line6$,
- $Pt2$ is the intersection of $Line2$ and $Line4$,
- $Pt3$ is the intersection of $Line2$ and $Line5$,
- $Pt4$ is the intersection of $Line5$ and $Line3$,
- $Pt5$ is the intersection of $Line2$ and $Line5$,
- $Pt6$ is the intersection of $Line4$ and $Line6$,
- Let consider the intersection between $Line6$ and BW . $Pt6$ is then *true* on this intersection line like some pixels to its right side. Then we keep only the farthest last *true* pixel to its right side on this line, this is $Pt7$.

In order to determinate the last line and points, we need some tests:

- let consider the *false* points of the intersection between $Line6$ and BW between $Pt7$ and $TipPt$. Let name them $Pt8_tmpX$ where X is the number of the point on the line.
- for each $Pt8_tmpX$ point we compute the line perpendicular to $Line6$ going through the considered $Pt8_tmpX$ point. Let name them $Line7_tmpX$.
- for each one of $Line7_tmpX$ line, we compute the distance between its $Pt8_tmpX$ and the first *true* pixel of BW . We keep only the higher distance computed and its number. Finally, the so found $Pt8_tmpX$ and $Line7_tmpX$ are $Pt8$ and $Line7$.

And last:

- $Pt9$ is the intersection of $Line6$ and $Line7$
- $Pt10$ is the intersection of $Line2$ and $Line7$

The 5 measures Lh , Lc , Lp , $Depth$ and Gap can then easily be computed as the distances between the points from 1 to 10.

Fig. 10 provides the points and lines from the step 4 for an sample fishhook.

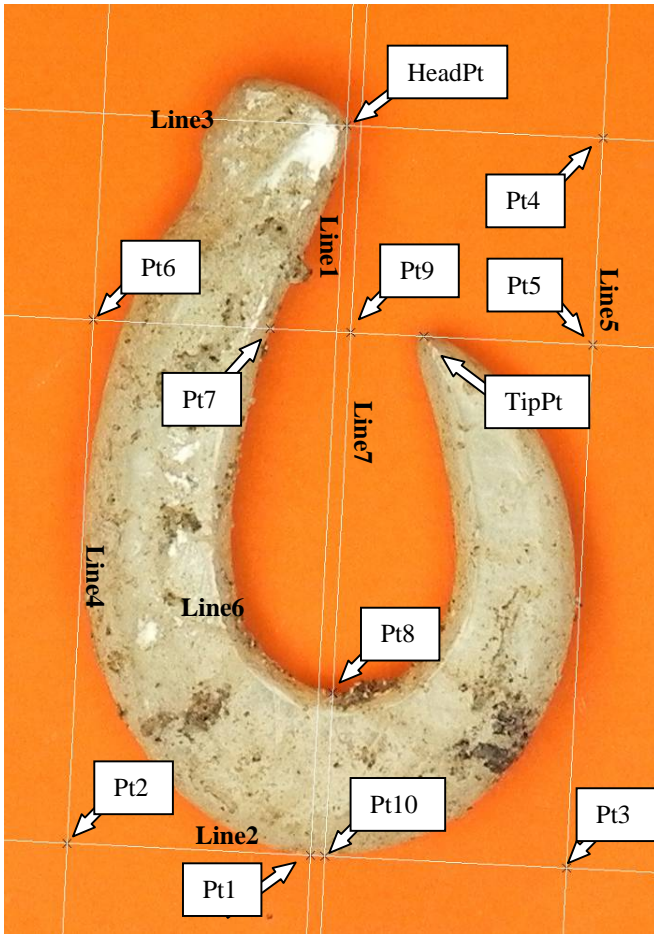


Fig. 10 Sample of resulting points and lines of the automated objective method on a sample fishhook

V. EXPERIMENTAL RESULTS

We have at our disposal a set of several hundreds of fishhooks from the three sites of Ua Huka: Manihina, Hane and Hatuana. Among them, only 41 are in perfect state without any break. We have applied the previously proposed method to all of these fishhooks in excellent condition.

We also applied this method manually on a paper printout of the same image that the one used by the automatic measurement program proposed in this study. We then manually plot all lines and points needed for the objective method proposed in [1].

The maximum precision of the human experts is the half of a mm on the printout due to the width of the tip of the criterion which is 0.5mm.

We first present some measuring results on two fishhooks samples, and then we discuss the measuring results globally on the whole good condition fishhooks set we have.

A. Measures Sample n°1

The Fig. 11 presents the resulting lines and points of the automated method proposed in this study of the fishhook SU98-10a which come from the excavation site of Manihina. The Table I provides the measuring results of this fishhook using different measurement methods.



Fig. 11 Automatic measures on the fishhook SU98-10a

TABLE I
 COMPARISON OF DIFFERENT MEASURING METHODS ON THE FISHHOOK SU98-10A IN MM

SU98-10a	Lh	Lc	Lp	Depth	Gap
Manual Measure converted values	13,95	8,06	4,68	2,90	5,65
Automatic measures Front	13,94	8,03	4,70	2,95	5,63

If we focus on the results of the automatic method proposed in this paper, we can see that the difference is in the worst case of 0.05mm according to the measurements of an expert using a full A4 printed page of the fishhook and that plots all the lines and points of the method.

B. Measures Sample n°2

The Fig. 12 presents the resulting lines and points of the automated method proposed in this study of the fishhook D8-24a which come from the excavation site of Hane [10].

The Table II provides the measuring results of this fishhook using different measurement methods.



Fig. 12 Automatic measures on the fishhook D8-24a

TABLE II
 COMPARISON OF DIFFERENT MEASURING METHODS
 ON THE FISHHOOK D7-46A IN MM

D7-46	Lh	Lc	Lp	Depth	Gap
Manual Measure converted values	23,43	15,13	14,76	10,70	8,12
Automatic measures Front	23,40	15,10	14,74	10,69	8,15

As in the previous example, we can notice very little difference of less than 0.03mm between the automatic measurements and expert measures on a printout of the fishhook.

C. General Results

The Table III summarizes the difference of results of manual and automatic measurements on all 41 perfect full fishhooks available to us.

TABLE III
 SUMMARY OF THE DIFFERENCE OF MANUAL AND AUTOMATIC MEASURES ON THE WHOLE DATABASE IN TENTHS OF A MM

	Lh	Lc	Lp	Depth	Gap	Imprecision
Std dev	1,03	1,19	0,94	0,88	1,04	NA
Mean	1,36	1,51	1,24	1,16	1,39	1,06
Min val	0,03	0,11	0,09	0,15	0,08	0,87
Max val	3,86	3,92	3,37	3,32	3,68	1,32

The last column shows the results of a measurement error of half a millimeter on the printing with respect to the scale used. The average measurement error of half a mm on the printing results in a real measurement error of about 0.1mm and 0.132mm in the worst case.

We computed the difference between each measurement realized automatically and manually, and then we computed

their standard deviation, their average, minimum and maximum.

Then we can see that the maximum difference between the automatic and manual measuring methods do not exceed 0.4mm in the worst case. This is in agreement with the manual measurements protocol which was achieved with a fine tipped criterion of 0.5mm.

The mean deviation of measurement varies between 0,116mm and 0,151mm and the standard deviation between manual measurements and automated measurements ranges between 0,088 and 0,119mm. These measures are pending with the needs of ethno-archaeologists who need a precision of about 0.5mm in the worst case.

As a final result we can state that all automatic measures of a fishhook takes less than a minute in the worst case on a PC with an i7 960 and a Matlab used for the implementation. As comparison, an expert takes about 7 to 8 minutes to complete all steps of a single hook manually.

VI. CONCLUSION

In Polynesia, fishhooks and their measures are chronological indicators and essential in the reconstruction of fishing methods for the ethno-archaeologists. The usual way of measuring them consisting in manual guesswork measures generates too much measuring errors (more than 0.5mm on the 41 fishhook of this study between 2 different experts) because of the non standardized position of the fishhook. A new objective measure was proposed in [1] to overcome this problem. The major problem is that it is really time consuming if done correctly.

In this paper, we proposed an acquisition protocol for acquiring pictures of the fishhooks that facilitates their extraction from the background. We also proposed an automatic method to extract the fishhooks and to get their key points to be able to precisely measure them. We applied our method on a corpus of 41 fishhooks from 3 excavation sites and compared them with manual measures using the objective method proposed in [1] on enlarged printouts to get the more precision possible. We obtained a precision under 0.4mm which is better than the needs of the ethno-archaeologists.

This study is the first part of a much larger study that will consist in recognizing the type of fishhooks fragments available to us, and then rebuild and measure objectively and automatically them.

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