The WANDA Measurement Tool for Forensic Document Examination

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Abstract: *This paper introduces the WANDA Measurement tool (WAM) for forensic document examination. The WAM is an essential component of WANDA, a workbench that supports the user in the complete task flow of processing documents, measuring characteristic features in handwritten documents, and writer search. By using technologies like plug-ins. XML, and client/server modularity, a system was created that is easy to maintain. portable, and highly adaptable. Within WANDA, the WAM is the tool for interactively measuring handwriting features. The WAM was developed based on recommendations from a comparison study between two forensic writer identification systems, Script and FISH. It incorporates nine measurements identical to those of FISH, and a new allograph measurement that is discussed in this paper. Furthermore, its intuitive new user-interface reduces the steep learning curve and streamlines the working process. A comparison of features previously measured by forensic experts using FISH, with measurements obtained through WANDA, assessed the precision of the WAM. It has shown that the small deviations yielded fall well within the possible imprecision caused by scanning or preprocessing operations, and far below the standard deviation of FISH measurements. Finally, results from usability tests with expert and novice users show that the WAM is easy to use.*

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l. Introduction

Since 1986, the Forensic Information System on Handwriting (FISH) (Phillip, 1996) has been used by the German law enforcement agency Bundeskriminalamt (BKA). Various other forensic institutes such as the US Secret Service and the Dutch NFI also make use of this tool. FISH is a handwriting analysis and writer identification system that enables the user (a forensic handwriting expert) to measure the features of a piece of handwriting. Based on interactive measurements and automatically derived features from a scanned piece of handwriting, FISH is able to perform a writer search. This search ranks the handwriting samples already in the database according to their similarity to the questioned sample. This considerably speeds up the task of the expert by reducing the number of documents that require manual inspection. Schomaker and Vuurpijl (2000) concluded from a comparison between FISH and the Dutch system Script (de Jong, Kroon & Schmidt, 1994) that although FISH is an excellent system when it comes to writer identification results, the user-interface of FISH should be improved. Furthermore, a technological update was necessary to improve its portability and ease of maintenance.

In a joint initiative led by the Fraunhofer IPK, an international group of institutes has developed a

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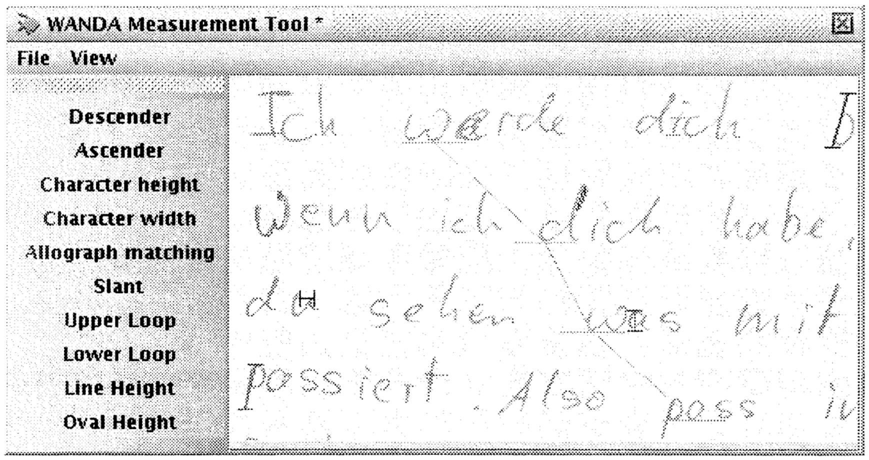

FIGURE 1: The main window of the WANDA measurement tool (WAM).

prototype for a new handwriting analysis and writer identification system, christened WANDA (Franke et al., 2003, 2004; WANDA, 2004). Modern forensic handwriting examination tools are either still under research (an overview can be found in Srihari and Leedham (2003)) or are commercially available (Lum enIQ, 2004; Pikaso, 2004), but lacking in sophisticated pattern recognition techniques. The WANDA system provides a large update to FISH. This update consists of technologies such as network access, client/server modularity, exchangeable plug-ins and human readable XML messaging and storage. The new system was built in Java, using highly portable public domain software and no proprietary data formats. These technical updates ensure that the system is up to date with current developments, platform independent, and easy to expand and maintain. WANDA also uses new research in pre-processing (Franke & Koppen, 2001), data standards for annotation and storage (Franke, Guyon, Schomaker & Vuurpijl, 2003), automatic writer search (Schomaker, Bulacu & van Erp, 2003), and on-line pen support (Franke, Schomaker & Penk, 2003). Furthermore, WANDA allows for multi-language support (Dutch, English and Gennan are currently supported) and has a new user interface that conforms to the standard interfaces that current computer users are familiar with.

The focus in this article is on one specific tool in the WANDA workbench, the WANDA Measurement tool (WAM). The WAM enables the user to perform interactive feature measurements on handwriting. The first priorities of the WAM were to improve user friendliness, reduce the amount of labor involved during measurements, reduce the amount of subjective interpretations by the user on the measurements, and allow novice users (police officers entering evidence at the office) to be able to work with the system, while retaining the possibility of fast expert (forensic scientists at the lab) usage.

In this paper, the WAM user-interface will be illustrated. The *allograph* measurement, a new measurement introduced in the WAM, will then be described. Subsequently, we will present our validation of the acquired measurement values by comparing them to FISH measurements on images from the BKA databases. A further validation of measurement features was performed by comparing data from different sources. Finally , the usability study that was performed on the WAM to validate the user-interface is discussed.

2. The WAM user-interface

One of the main goals of WANDA was to design a modern, easy-to use, user-interface. In this section we will describe how this was accomplished for the WAM interface. To better understand the WAM and its user interface, it is necessary to see how the WAM fits into the WANDA workbench. When a user has a piece of handwriting that needs to be examined and identified, some steps have to be taken before the WAM can be used. Our experience shows that this is true for practically all writer identification systems.

The user will first scan the handwriting. The scanned image is stored in the WANDA database and

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WANDA Measurement Tool – Summary

Measurement	#	Average	SD
Character height	11	2.54	0.61
Character width	10	2.29	0.69
Descender	10	5.55	0.9
Ascender	10	6.27	0.65
Oval Height	10	2.49	0.26
Slant	10	66.19	12.44
Allograph	10	0	0
Line Height	11	8.07	0.25
Upper Loop Size	14	2.91	0.73
Upper Loop Form	14	7.34	2.28
Upper Loop Slant	14	57.79	3
Lower Loop Size	11	1.77	0.7
Lower Loop Form	11	2.12	0.53
Lower Loop Slant	11	58.03	18.4

OK

FIGURE 2: Measurements. For a description of each measurement see Section 2.3.

will be the basis for all subsequent steps. From the scanned image the user can select a *region of interest* (ROI). A ROI is the piece of the handwriting that the user is currently working on, typically a rectangular or polygonal sub area from the original scan. The ROI concept was introduced for multiple reasons: (i) it may be suspected that more than one writer produced the handwriting, (ii) only certain areas of the scanned image may be relevant (i.e., contain handwriting) , and (iii) it is often more convenient to work on a part of the entire image to get a more detailed view. Note that the user can use the entire image as a ROI, if that is preferred.

When a ROI is selected, it can be processed by one or more functions from the WANDA workbench, including the WAM. In most cases, the advanced image pre-processing tool of WANDA should be used before any further processing. With this tool, regions of interest can be cleared of any parts that do not belong to the handwriting that can interfere with precise measurements (such as background, bleed through or residues from the scanning process). After pre-processing, the WAM can be employed to interactively measure handwriting features (see below). Subsequently, the measurements can be stored in a database or they can be used as features for writer search. WANDA can access any previously run sessions to display, continue, or correct measurements..

2.1 The WAM main window

The WAM interface consists of a main window and a measurement window. The main window in the WAM (Figure 1) provides an overview of all measurements that have been performed on the current ROI. The measurements are color-coded by type, to enable the user to quickly identify them and to avoid cluttering the image. The items (buttons) on the left side of the window provide a clear overview of the ten available measurement types of the WAM.

An overview of measured features is presented in a table that can be accessed via the view option. For each measurement type, the number of measurements contained in the current ROI, their average value, and standard deviation are depicted (see Figure 2: note that both loop measurements result in 3 values each).

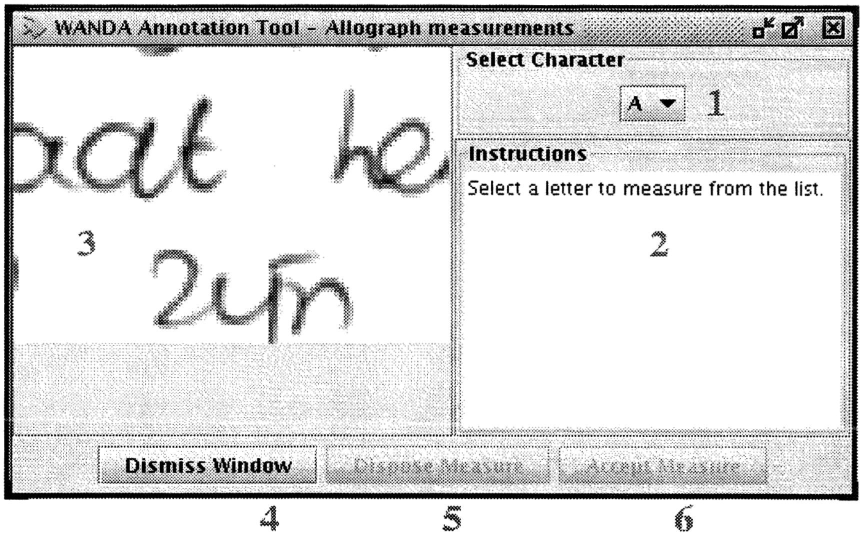

FIGURE 3: The measurement window of the WANDA measurement tool.

2.2 The WAM measurement window

Each measurement type can be initiated at any time. Upon starting a measurement type, the measurement window is opened. This is the first step for all measurements (see Figure 3). Part of this window (nr. 3 in Fig. 3) depicts the ROI containing the selected piece of handwriting.

All but the line distance feature measurements are performed on characters. The following sequence of actions is performed when measuring a particular character feature contained in the depicted **ROI.** All of these actions can be performed via the mouse, but accelerator keys are provided as well, allowing fast and efficient interactions for expert users:

1. The corresponding character from the drop down list is selected (nr. 1);
2. The user will start measuring the feature (see Section 2.3 below);
3. The control buttons (nrs. 4, 5, and 6) arc used to either: (i) quit, (ii) cancel, or (iii) accept and finish the current measurement.

During this process, the instruction window (nr. 2) guides the user step by-step through the measurement. The usability studies described below indicate that this dynamic, context-dependent help functionality allows novice users to perform the task of measuring well, while it does not hinder expert users in any way.

2.3 Interactively measuring features

The process of interactively measuring features is supported by the WAM in several ways: (i) users are assisted with context-dependent guidelines, (ii) for all measurements, the WAM performs an automated search for “ink pixels” in the scanned image, (iii) all performed measurements are rendered in a uniform, consistent and understandable way, and (iv) users are guided in the process of browsing, viewing, selecting, and correcting measured features. The WAM supports ten different measurements. These consist of the various character heights (ascenders, descenders, corpus height, and height of oval characters), the slant of characters, and the character width. Furthermore, if they are present in the handwriting, the WAM allows users to measure the upper and lower loops of characters. The line distance is the only non-character based feature measured via the WAM, representing the average distance between the baselines in a piece of handwriting. The tenth measurement, the new allograph measurement, is discussed in detail in the next section. The other nine measurements are identical to the measurements per formed in FISH. We will give a brief summary of the measurements below. A more detailed description of the supported measurements is given in Phillip, (1996).

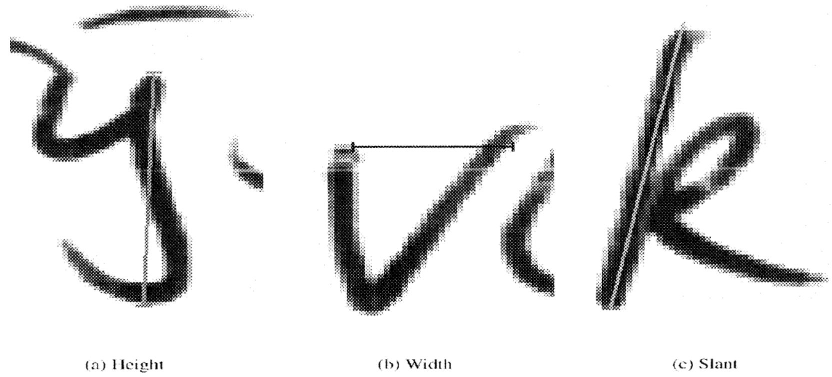

FIGURE 4: Typical examples of the height, width and slant measurements.

2.3.1 Height measurements: Ascenders and descenders are measured from the top to the bottom of the vertical strokes (not necessarily the top and bottom of the letter). Character heights are measured on the vertical strokes extending from the baseline to the corpus line (e.g. in the *n*, *u* and *i*), while oval heights are measured as the distance between the top of the oval part of letters like *a*, *o* and d and the bottom of that oval. All measurements start at the first ink pixel and end at (and include) the last ink pixel. (See Figure 4a for an example of a descender measurement.)

2.3.2 Line heights: The line height (also called the interlinear spacing or line spacing), the distance between two consecutive baselines, is measured from the bottom pixel of a letter on the first line to the bottom pixel of a letter on the consecutive line.

2.3.3 Character widths: The width of a character is measured on 'cupped' letters (e.g. *u* and *n*). It is the distance from the right edge of both cup-ends (i.e. the inside of the letter on the left side and the outside of the letter on the right, see Figure 4b).

2.3.4 Slants: The slant (see Figure 4c) of characters is measured by drawing a line on an ascender (preferably, though descenders are allowed). The angle between the drawn line and the x-axis is considered the slant of the letter.

2.3.5 Loop measurements: By clicking inside a loop, the WAM will trace its inner edge, determine the longest and shortest length across this trace, and return as measured values the longest length, the ratio between the longest and shortest length (the form of the loop) and the slant of the longest length line. These three values are used to characterize the loop.

3. Recognition-based measurements

The nine measurements described above are relatively standard features in forensic handwriting examination. This section describes how the WAM supports another well-established feature, the examination of prototypical character shapes, or allographs, in handwriting.

The utilization of allographs in forensic document examination is a labor- intensive task that requires large amounts of expertise and skill from the document examiner. A particular task which must be performed is the detection of specific character shapes in a handwritten document and the comparison of these shapes to allographs from another document, to assess whether the same writer produced both documents. Another even more challenging task is to compare allographs from one document to allographs from a set of documents, to identify the writer.

The tenth measurement in the WAM is designed with the goal of automating these tasks. Our studies have shown that comparing character shapes to a set of prototypical allographs using handwriting recognition techniques is feasible and yields acceptable recognition results (Vuurpijl & Schomaker, 1997). The allograph measurement of the WAM builds on these recognition-based techniques, called allograph matching, for annotating a handwritten document with a set of allographs. During this meas-

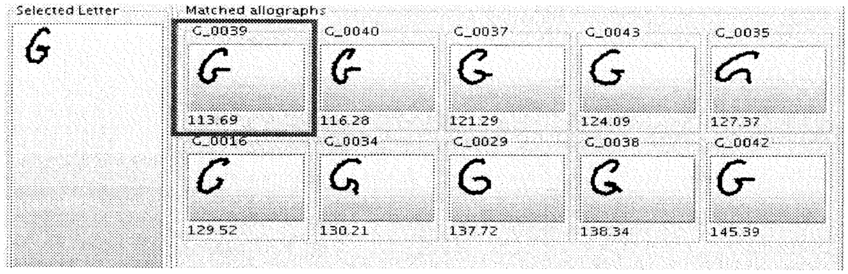

Figure 5. The presentation of allograph prototypes.

urement, the user is asked to trace a character in the questioned document by pen-tablet or mouse. This creates an online trajectory of the allograph. The trajectory is subsequently matched to a database of online allograph prototypes. This set of prototypes comprises 2414 lower case and 1115 upper case prototypes, obtained through the hierarchical clustering techniques described in Vuurpijl and Schomaker (1997). More than 1500 writers, producing hundreds of thousands of characters, were used to create these allograph prototypes. The WAM will present the best matching prototypes for the user to choose from (see Figure 5). The label of the best matching prototype the user selected is used as one of the features in writer identification. In this way, documents can be annotated (indexed) with a limited set of allograph prototypes. Given a dataset of documents annotated with allograph prototypes acquired by using the WAM allograph matcher, the forensic document examiner will be able to query the database and retrieve all documents that contain a particular character shape.

4. Validation of measurements

One of the difficult requirements of the WANDA project was that the resulting measurements should be compatible with the FISH measurements. FISH has been used for over a decade and a large database of cases has evolved (77.000 as of December 31st, 1997). Not meeting the compatibility constraint would make this huge pool of data useless. The measurements from the WAM, therefore, should very closely resemble the measurements from FISH.

A procedure was conducted to ensure that the results obtained through WANDA are valid by: (i) examining whether features measured from paper match features measured on a corresponding scanned image,(ii) assessing whether features measured through the WAM are identical to features measured from the corresponding scan, and (iii) to compare features measured through the WAM with corresponding features measured via FISH. Note that there are several sources of variation when examining scanned documents. First, different environmental conditions (e.g., temperature, humidity, storing, or scanning conditions) may cause paper to shrink or extend some millimeters (mm). Second, as many measurements are performed on the edge pixels of handwriting material and because preprocessing operations on the scanned images (e.g., filtering or thresholding) particularly operate on such edge pixels, differences may be caused between the paper version and the scanned image. Furthermore, edge pixels in general contain both ink and background. Yet, even if only part of a pixel consists of ink, it is still considered an ink pixel. For these reasons, the features on paper and those on the scanned image may differ by up to 2 pixels (1 pixel per edge, 2 edges measured per feature). For a typical 300 dpi scan (1 pixel corresponds to 0.085 mm), differences of within the 0.170 mm range should still be considered as accurate.

The first validation assesses whether image-based measurements from a scanned image can be compared to the actual handwriting on paper. In a small study, this "scan validation" compared twenty measurements (height and width) from ten parts of signatures written on paper. Measurements were performed with a high-resolution optical microscope (5 μm resolution). These were compared to the scanned version of the same signatures by using an image visualization program. Subsequently, the number of pixels was counted in order to assess the correspondence to the measured values on paper. Measured heights (by microscope)

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Type	Mean (FISH)	Stdev (FISH)	Mean Difference	Minimum Difference	Maximum Difference	Stdev Diff.
Width	2.045 mm	0.387	0.025 mm	-0.080 mm	0.100 mm	0.048
Height	1.682 mm	0.321	-0.010 mm	-0.100 mm	0.160 mm	0.091
Ascender	3.843 mm	0.402	0.058 mm	-0.160 mm	0.170 mm	0.130
Descender	4.418 mm	0.678	0.045 mm	-0.100 mm	0.240 mm	0.112
Oval	1.802 mm	0.279	0.020 mm	-0.160 mm	0.170 mm	0.107
L. Height	6.526 mm	0.827	-0.033 mm	-0.110 mm	0.000 mm	0.047
Slant	69.37°	7.51	-0.38°	-2.00°	1.80°	1.16

TABLE 1: The analysis of the differences between WANDA and FISH measurements.

were within [2.21-7.14] mm, widths within [l.12-5.91] mm. The deviations in the measured scans were below 0.165 mm for both heights and widths.

In the second validation, three expert users each measured 10 features from l0 different scanned documents with the WAM. These features were compared to the number of pixels manually counted from the visualized scan. As all results (total 300) yielded precisely the expected values, the conclusion was drawn that the WAM measures correctly .

The third validation assesses whether the two systems FISH and WAM yield similar values. The exact same measurements obtained using FISH were measured through the WAM. The validation was done on 11 documents provided by the BKA. Experts from the BKA, using FISH, measured these documents. For each document a printed image with the original FISH features was available, including the corresponding (enlarged) printed versions of regions of interests. Each of these prints contained annotated material that indicated how and where the FISH experts measured features. Each of the 11 original documents was scanned using the WANDA scanning facilities. All FISH measurements were carefully redone in the WAM tool, with these prints as reference material for guidance through all measurements. Subsequently, the results of the WANDA tool were compared to the archived results.

It should be noted that the FISH measurements were performed in 200 dpi resolution, while the WANDA scans were in 300 dpi, which is currently considered to be the absolute minimal resolution which should be used for forensic document examination. As a result, the edge of the ink will be covered differently by partial ink pixels. This difference may be as high as l pixel per edge. For this validation, therefore, even if FISH and WAM would normally yield similar results, a deviation of up to two (300 dpi) pixels is still possible. Furthermore, each of the newly scanned images were preprocessed using WANDA, which may have caused an extra deviation (in the 2-pixel range).

A third possible source of deviation is introduced by the human user, as it is unavoidable that some measurements done in WANDA differ slightly (one or two pixels) in placement compared to FISH. The printed guidelines were at times not clear on the (very) precise location of a measurement, so a subjective choice had to be made.

Table 1 shows the results of the validation. All differences are from WANDA to FISH, (i.e. negative numbers) and signify that the WANDA measurement was smaller than the FISH measurement. The second and third columns represent average values and corresponding standard deviation for each measurement type. Please note that even the maximum differences between the WAM measurements and the FISH measurements are within the standard deviations of the FISH measurements. From the results we can conclude that, except for the descender and slant, the differences between FISH and WANDA fall within two pixels (0.17 mm) for all measurement types. Furthermore, each average difference falls well within the 1-pixel range (0.085 mm), indicating that the differences measured are divided more or less equally over “too high” and “too low”. In the case of the descender, the high point of the range is outside the 2-pixel boundary. However, there was just one document pair for which the results differed in this way. The next instance in this range lies over a millimeter lower. The precision of the slant falls within a 1-pixel range. To change one of the end points of the slant measurement by 1-pixel, it is possible to create a difference of well over 2. Based on these validation results, we conclude that the WAM features are compatible with FISH.

5. Usability study

In this section, the results from a usability study of the WAM are presented. Since the project aimed at a system that was usable by both expert and novice users, four experts and ten novice users tested the system. The experts were users who had worked with FISH from the BKA (2) and the NICI (2). Their input was invaluable, as they were capable of judging WANDA compared to its predecessor FISH. The ten novice users, on the other hand, had no experience at all with writer identification or handwriting measurements. Their opinions of the system, therefore, would be from an entirely different view than the view of the experts.

The usability study for the WAM was conducted with five documents per user. For each document, the user had to measure 10 instances of every kind of measurement. The exceptions were the two loop measurements, as not all handwriting styles include loops. Loop measurements were only to be taken if enough (5 at least) of a kind were present in the handwriting. The novice users had to read the WAM manual first. After the measurements, all subjects were asked to give a list of good and bad points of the WAM. The novice users were also asked if they encountered any difficulties after reading the manual. Furthermore, their results were checked on errors to see if they understood the instructions correctly.

The overall results of the usability test were very encouraging. With only the manual and the instruction window of the measurement tool it self to help them, the novice users were able to quickly start measuring. Most errors made were consistent with errors made through misinterpreting the instructions (e.g. a descender was measured on the entire height of the letter instead of just on the descender stroke), rather than a confusing interface. Furthermore, after the first document was processed, the rest of the documents were measured considerably faster. The average user finished the first document in 40 minutes to an hour, while each document after the first was done in 20 to 30 minutes. Moreover, the measurement time for later documents was approximately equal to the time an expert takes to measure them (20 minutes). This indicates that the novice users learned how to use most of the system after measuring a single document.

Two measurements did show errors that are harder to correct. Both the line height and the character width were often measured incorrectly. While part of this can be explained by misreading the instructions, some useful remarks can be made.

5.1 Line measurement: The line measurement, in its present form, appears to be rather confusing for most novice users. Most users (8 out of 10) failed to sec that a line measurement is a measurement on the complete lines that are used. Once a pair of lines is measured, it should not, as a pair, be used again in another line measurement. However, users repeated measurements on the same lines for different line height measurements. They would, for example, measure a line height at the beginning of two lines and then measure another line height at the end of those same lines. This should be more clearly indicated in the instructions. Alternatively, the depiction of the measurement could cover the whole baseline each sentence, signifying that the line was used already.

5.2 Width measurement: The width measurement is a difficult measurement, even for experts. The ideal width measurement is taken on letters that contain a cupped form and is performed at the edge of the open end of the cup (see Figure 4b). It appears that this is hard to explain to a novice user. Furthermore, many forms of handwriting (especially when they are sloppy and/or cursive;) produce forms of the ‘n’ and ‘u’ that are not suitable for this measurement. This makes the explanation of the character width to novice users even harder to accomplish.

Novice users apparently find most measurement types intuitive and easy-to-use, but the width and line height measurements belong to a more difficult category. We are currently designing more elaborate

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instructions for guiding users in these difficult measurements.

We also asked the users if they thought that the WAM worked well overall and whether they found some points that needed improvement. All users agreed that the WAM was easy to use and they saw no major problems. Some users made small suggestions for improvements that were of a more personal nature (in most cases a suggestion was only put forth by one person), but we are still evaluating their impact.

The results of the usability study were positive overall. Both novice users and experts found the system easy to learn, easy to use, clear, and intuitive. The novice users were able to use the system correctly after studying the manual and with the help of the instruction window.

6. Conclusion

WANDA is a technical and ergonomic update of the FISH writer identification system that incorporates state-of-the-art technologies, resulting in an up-to-date, flexible, and open system. This makes it easy to maintain, portable, and easy to extend.

The WAM tool is the part of WANDA that interactively measures handwriting features . The WAM offers a new user-interface that employs color and textual cues to give the user a clear and functional overview of the current state and the possibilities of the tool. It also provides a proof of-concept for recognition-based measurements in the form of the new allograph measurement. The validation of the WAM shows that the system yields no substantially different measurement results when compared with FISH, which ensures its compatibility. Furthermore, the interface design is sound and usable by both expert and novice users. Our current efforts are targeted on (i) improving the user-interface based on the out come of the usability study, (ii) further developing the recognition-based annotation techniques like the WAM allograph matcher, and (iii) using WANDA to enlarge our current databases of measured documents in order to assess our writer search techniques.

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