User Manual

Defense Fingerprint Image Quality Index

v1.0

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Overview

Introduction:

The *DFIQI* software is a quality assessment software for friction ridge skin impression evidence. It measures the clarity of friction ridge impression minutiae and provides a quantitative assessment of the overall quality of an impression for comparison and evaluation purposes as it relates to determinations of Value, Complexity, and Difficulty of the impression during Analysis.

This *DFIQI* user manual provides detailed instructions for installing, operating, and interpreting the results.

Operating Requirements:

DFIQI is a macro plugin to ImageJ. ImageJ is a public domain Java image processing program developed by the National Institutes of Health (NIH). *DFIQI* utilizes the ImageJ architecture, but is assembled as a stand-alone software interface for the end-user and can run on any Windows PC with Java 1.4 or later. The software is able to process 8-bit, 16-bit, and 32-bit digital images in many image formats, including TIFF, GIF, JPEG, and BMP.

Installation:

DFIQI may be installed using the *DFIQI* setup executable by following the onscreen instructions. *DFIQI* will be installed on the local user machine at the directory location specified during installation. A shortcut icon may be installed on the desktop.

Operating Instructions

Image Preparation & Requirements:

DFIQI accepts images in one of the following file formats: TIFF, GIF, JPEG, or BMP. Images MUST first be converted to grayscale then converted to RGB color *prior* to annotating any features. Images may be either 8-bit, 16-bit, or 32-bit. Images do not need to scaled to a set resolution prior to input in *DFIQI*; however, the user must be able to specify the resolution of image and they should be at least 500 pixels per inch (ppi).

Feature Annotation:

The features must be annotated using color annotations (any color except red) in Adobe Photoshop® or any other standard image analysis software after the image itself has been converted to grayscale and then back to RGB-color (to ensure the only colored pixels are those corresponding to feature annotations). Features must be annotated such that the feature base is at least 5 pixels in diameter. Feature annotations must also have clearly drawn tails indicating the direction of ridge flow. The feature tail lengths must exceed the diameter of the feature base annotation. Feature annotations must NOT overlap one another. Features should be indicated by placing the base at the end of the ridge ending or bifurcating point of a bifurcation. The tail should be drawn in the direction of ridge flow (for ridge endings, the tail should extend along the ridge; for bifurcations, the tail should extend between the bifurcated ridges). Dots may be annotated as a single ridge ending from either direction. Figure 1 below demonstrates how features should be annotated.

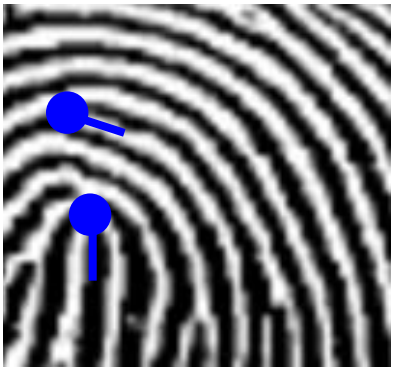

Figure 1: Illustration of proper feature annotation for ridge endings and bifurcations

Feature annotations on the same image should be consistent in size. Feature annotations should be done using "hard" edges and should not be done using "soft" edge settings. Once features are annotated, the images must be saved in a "lossless" file format to avoid obscuring the feature annotations during compression.

Features may be annotated using a built-in annotation tool within *DFIQI*. To annotate features using *DFIQI*, follow the steps below:

(1) Click the "f" key on the keyboard to activate the feature annotation tool.

(2) Annotate each feature by left-clicking the mouse on the base of the feature, hold down the left-click button and drag along the ridge flow to indicate the feature tail angle. Release the left-click button to annotate the feature. Features will appear in red. These are "tentative" and can be edited.

(3) If a feature needs to be edited or deleted, select the feature identifier using the ROI Manager window (the feature selected will become highlighted on the image) and then select "delete". Then re-draw, if necessary.

(4) When finished annotating, click the "space" bar on the keyboard once. This will "Accept" the feature annotations, turn them blue color, and flatten them onto the image. Once this occurs, the user can run *DFIQI* analysis. NOTE: when annotating in the *DFIQI* application, the same rules apply for feature annotations – the most important one being that features cannot overlap one another.

Dashboard Interface:

DFIQI may be initialized by double clicking the desktop shortcut icon. Upon initial execution, the ImageJ dashboard interface may initially appear followed by the dashboard interface for *DFIQI*. The *DFIQI* interface contains six buttons, illustrated below:

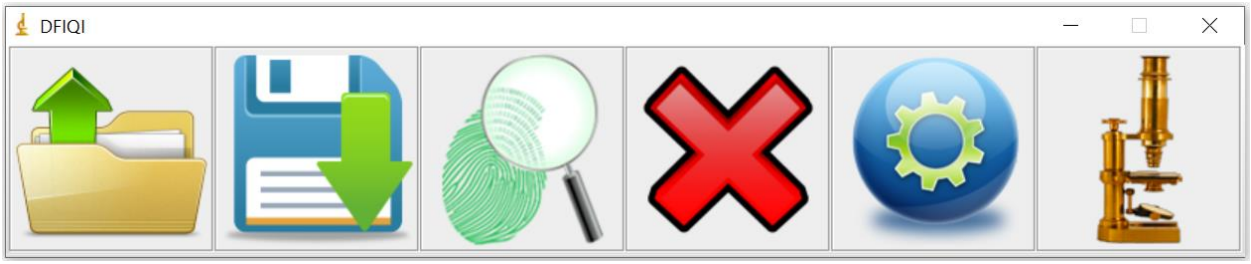

Figure 2: DFIQI dashboard. From left to right: "Open", "Save", "Run", "Close", "Options", and "ImageJ".

"OPEN"
Users may open friction ridge skin images from a specified directory.

"SAVE"
Users may save friction ridge skin images in a specified file format and in a specified directory.

"RUN"
Users may initiate the *DFIQI* application. NOTE: the image MUST be open within *DFIQI* prior to initiating the *DFIQI* application.

"CLOSE"
Users may close the *DFIQI* application and dashboard interface. NOTE: users should use this icon to ensure all applications close. If the small "x" in the upper right-hand corner is used to close *DFIQI*, the ImageJ application will remain open in the background and could cause delays or issues when attempting to re-open *DFIQI*.

"OPTIONS"
Users may view overlays of the detected features, color coded based on local feature scores (LQS values), and "flatten" the overlay directly onto the image for archival purposes.

"IMAGEJ"
Users may toggle between showing and hiding the ImageJ interface. Any functionality available within ImageJ may also be applied to the images. Reference ImageJ specific documentation for how to utilize ImageJ functionality.

Operating *DFIQI*:

Open Images

Images must be opened using the *DFIQI* "open" tool (figure 3). Images may be opened from any directory location accessible to the user (on the local machine or from a network accessible directory location).

Figure 3: DFIQI "open" image icon on the dashboard interface.

Run DFIQI

Once an image is open, *DFIQI* can be run using the "Run" tool (figure 4).

Figure 4: DFIQI "run" image icon on the dashboard interface.

Once selected, users will be prompted to specify the resolution of the image (pixels per inch), the GQS score(s) to be calculated for the image (options include: $Value_{GQS}$, $Complexity_{GQS}$, and $Difficulty_{GQS}$), and whether to have the feature overlay included on the output.

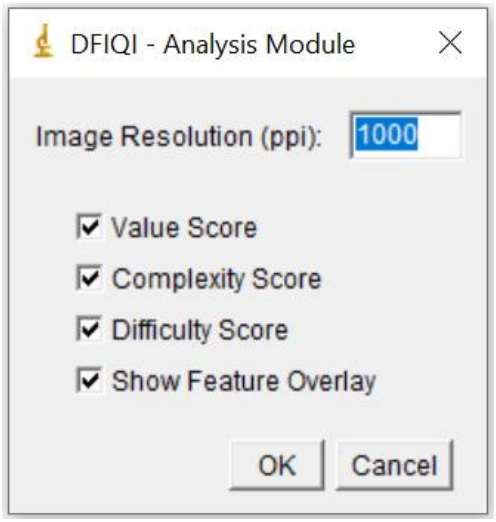

Figure 5: DFIQI interface to specify image resolution, the GQS score(s) to be calculated for the image, and whether to have the feature overlay included on the output.

Once the selections have been made, the user may select "OK" to initiate *DFIQI*. Once *DFIQI* is initiated, a progress bar will appear in the upper left-hand side of the screen. Once *DFIQI* is finished running, a copy of the image will be created and the results will be displayed in the upper left corner of the image.

Overlay Options

Users may view the *DFIQI* LQS feature overlay indicating features detected and the color-coded output for each feature score (green, yellow, or red) by selecting the "Options" icon on the *DFIQI* dashboard interface (figure 6).

Figure 6: DFIQI "options" icon on the dashboard interface.

Once the "options" icon is selected, users will be prompted to select "show overlay", "show overlay with labels", and "lock overlay" (figure 7).

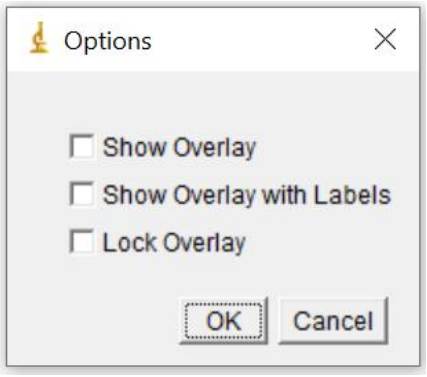

Figure 7: DFIQI "options" interface.

"Show Overlay" – selecting this option allows users to view the features detected by *DFIQI* as an overlay. Features will be color coded as green, yellow, or red based on their LQS scores (green indicating higher clarity and red indicating lower clarity).

"Show Overlay with Labels" – selecting this option will perform the same function as "show overlay", but will include a numerical label identifying each feature.

"Lock Overlay" – selecting this feature along with either "show overlay" or "show overlay with labels" also selected will flatten the overlay directly onto the image to permit saving the image with the overlay visible. NOTE: the "lock overlay" function cannot be undone.

In order to remove an unlocked overlay, users may select the image, select the "options" icon, ensure no settings are checked, and select "ok".

Concept of Operations

Feature Detection:

DFIQI detects the color feature annotations that have been made *a priori*. *DFIQI* requires that the only color pixels on the image are those which correspond to feature annotations. This can be accomplished by converting the image to grayscale and then RGB-color prior to the feature annotations to ensure the only color pixels on the image are those which correspond to the feature annotations. *DFIQI* isolates each separate instance of a contiguous grouping of color pixels, converts each group of pixels into a Euclidean distance map, and fits an ellipse to the group. The pixel value for each pixel in the group reflects the number of pixels between it and the edge of the group. As a result, the center pixel of the base of the feature will have the maximum pixel value. The x,y coordinate location of the maximum pixel value identifies the base feature location. The feature angle is detected by measuring the angle of the major axis of the ellipse. Figure 8 illustrates these concepts.

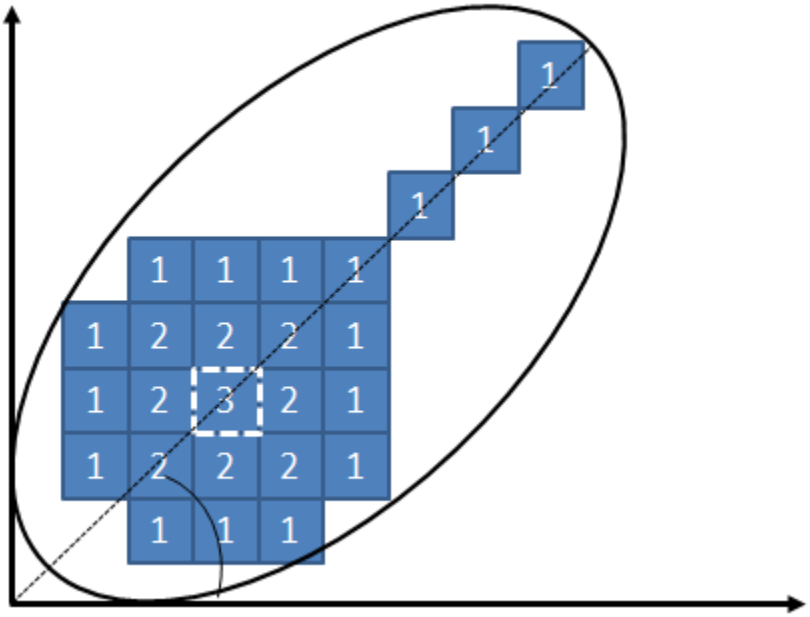

Figure 8: Each contiguous group of color pixels represents a single feature annotation. The pixel values represent the number of pixels between that pixel and the edge of the feature. The maximum pixel value represents the center of the bulbous portion of the feature annotation and serves as the x,y coordinates of the base. The major axis of the ellipse (dotted line running along the length of the axis) represents the angle of the feature.

Local Quality Score:

Once the x,y coordinates are identified for the features in the impression (e.g. by an analyst marking the location), the application measures the clarity and quality of the ridge detail immediately surrounding each individual feature in the impression using five predictor variables ("Signal Percent Pixels Per Grid", "Bimodal Separation", "Acutance", "Mean Object Width", and "Spatial Frequency"). The raw predictor values are each normalized and scored with a value between 0 and 1. The five normalized predictor values are then combined to create a mean univariate quantitative score (Local Quality Score, or LQS) summarizing the clarity and quality of the local region of friction ridge detail immediately surrounding the feature on a scale from 0 to 1 (higher values indicate higher clarity and quality). The LQS is then used as a basis to categorize and color-code the quality of the feature as a graphical output to the user (e.g., high, medium, and low). Features color-coded as green generally indicate areas of high quality, features color-coded as yellow generally indicate areas of medium quality, and features color-coded as red generally indicate areas of low quality.

Global Quality Scores:

Three different Global Quality Scores (GQS) values are calculated, each of which represent a summary of the overall quality of the impression for different purposes: to predict analysts' determinations of "value", "complexity", and "difficulty" as part of the Analysis phase of the examination methodology. For all three prediction categories (value, complexity, and difficulty), the GQS is calculated on a scale ranging between -1.00 and 1.00, where higher values indicate

stronger support for “value for identification”, “non-complex”, and “low difficulty”, respectively.

Interpretation

Local Quality Score:

Features color-coded as green generally indicate areas of high quality, features color-coded as yellow generally indicate areas of medium quality, and features color-coded as red generally indicate areas of low quality. LQS values between 0.35 and 1.00 are color-coded green (high quality), LQS values between 0.20 and 0.35 are color coded yellow (medium quality), and LQS values between 0.00 and 0.20 are color-coded red (low quality).

Global Quality Scores:

“Value” Determinations

The Value_{GQS} score can range from -1.00 to 1.00. Values near -1.00 indicate the impression is “not suitable” or “no value” and thus should not proceed for further comparison or should do so with caution and additional quality assurance safeguards in place. Values near 1.00 indicate the impression is “suitable” or “of value for identification” and may proceed for further comparison in accordance with normal operating protocols. A Value_{GQS} score of 0.50 is a reasonable threshold to characterize an impression as “value for identification.”

“Complexity” Determinations

The Complexity_{GQS} score can range from -1.00 to 1.00. Values near -1.00 indicate the impression is “not suitable” or “highly complex” and thus should only proceed to comparison with caution and additional quality assurance safeguards in place. Values near 1.00 indicate the impression is “non-complex” and may proceed for further comparison in accordance with normal operating protocols. A Complexity_{GQS} score of 0.33 is a reasonable threshold to characterize an impression as “non-complex.”

“Difficulty” Determinations

The Difficulty_{GQS} score can range from -1.00 to 1.00. Values near -1.00 indicate the impression is “high difficulty” and thus should only proceed to comparison with caution and additional quality assurance safeguards in place. Values near 1.00 indicate the impression is “low difficulty” and may proceed for further comparison in accordance with normal operating protocols. A Difficulty_{GQS} score of 0.00 is a reasonable threshold to characterize an impression as “low difficulty.”

Limitations

DFIQI is a tool that is designed to measure the clarity of friction ridge impression minutiae annotated by the user and provide a quantitative assessment of the overall quality of an impression for comparison and evaluation purposes as it relates to determinations of Value, Complexity, and Difficulty of the impression during Analysis. The major limitations of the method include:

1. The LQS and GQS values are dependent upon the subjective detection and annotation of friction skin features by the user.

2. The method relies on clarity attributes of friction ridge minutiae and does not consider all of the attributes that experts may consider when making subjective determinations, such as pattern type, feature type, rarity of features and their configurations, continuity of ridge detail between features, and other types of features (non-minutiae) available.

To attenuate these limitations, two general recommendations for policy and procedure could be considered. First, the method should be used *after* the expert has visually analyzed, detected, and annotated friction ridge skin features for which the expert has reasonably high confidence of their presence. Second, the method should be used as a framework for flagging impressions which may require additional quality assurance review. Although the method demonstrates reasonable consistency with experts' judgements, it should not be considered a replacement for the experts' interpretation. This method is a step toward greater transparency and objectivity, but is not designed or intended to supplant the careful interpretation of experts.

Troubleshooting

DFIQI relies on analysts' annotations between corresponding features and is sensitive to distance and angle measurements of the annotations. Improper annotations may cause *DFIQI* to result in an error or provide an incorrect result. Users may consider the following when troubleshooting issues related to *DFIQI*.

<u>Troubleshooting issues attributable to user annotations:</u>

The features must be annotated in a manner such that *DFIQI* is able to accurately detect the location and angle of each feature. Users may check how *DFIQI* detected the features by clicking the "t" key on the keyboard. A copy of the active image will appear with the features detected highlighted in red. Examples of common situations where DFIQI may not be able to accurately detect the feature location and/or angle include:

1. Annotations which overlap one another.

2. Annotations which have insufficient tail length.

3. Annotations which have "broken" tails (missing color pixels impacting the contiguous nature of the annotation).

4. Annotations made on an image prior to saving the image in a "lossy" file format (e.g. JPEG). The image compression may cause the feature annotations to distort and impact the ability for *DFIQI* to accurately detect the features.

Unresolved troubleshooting issues:

Circumstances involving circumstances in which the user is in disagreement with how the software evaluated the overall quality of the impression should be carefully evaluated and subject to enhanced quality assurance review. Conflicts between a user's interpretation of quality and the software's measurement of quality should be arbitrated in accordance with standard operating procedures.