Forensic Automotive Carpet Fiber Identification Database (FACID)

Preliminary Validation and Evaluation

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Abstract

The Forensic Automotive Carpet Fiber Identification Database (FACID) is a database currently being developed by the Laboratory Division of the FBI. FACID is collection of over seven hundred automotive carpet samples from personally-owned vehicles and automobile manufacturers. Questioned carpet-type fibers recovered in casework may be searched by microscopic characteristics, fiber type, and/or color information in order to determine if a particular category of vehicle was involved in a crime. Additionally, FACID can be searched by vehicle make, model, year, and/or color to determine the carpet samples that are available for comparison.

Introduction

Experimental Background

In forensic science analysis, carpet fibers of unknown origin are often discovered as trace evidence on a victim's person or clothing. More specifically, if the victim was transported or assaulted in a vehicle, carpet fibers from this vehicle may be collected. The establishment of an automotive carpet fiber database may aid investigative efforts.

The Forensic Automotive Carpet Fiber Database was constructed using Microsoft Access® and data collected from a variety of new and used vehicles, as well as from automotive carpet samples obtained directly from manufacturers. Data were collected via microspectrophotometry (to obtain visible spectra and color values), Fourier-transform infrared spectroscopy, and microscopy.

Following data acquisition, extensive validation studies were performed.

Features of the Forensic Automotive Carpet fiber Database (FACID)

The database currently contains seven hundred and sixty-six searchable files. Each file consists of several main searchable parameters, or fields, which are dependent upon the characteristics of each fiber: color, cross section, diameter, polymer class, presence/absence of delustrant, color distribution, presence/absence of striations, illuminate values, Visible spectral peaks (lambda maximum values). In addition to the primary fields, additional information concerning the source of the fiber is also included: vehicle make, model, year, vehicle identification number (VIN), color, body style, overall carpet color, location of the vehicle from which the carpet sample was obtained, a photographic representation of the fiber, and any notes of relevance, such as dichroism. Although these additional fields may also be searched, it is unlikely that such information is available for questioned fibers.

Qualitative data, which include color(s), cross section, polymer class, delustrant, color distribution, and striations, are entered and stored in FACID via a series of selection menus and options. Quantitative data, on the other hand (diameter, illuminate, and lambda maximum values), are entered into the database as numerical ranges. In the cases of illuminate and lambda maximum values, the ranges are based upon standard deviation values and are obtained via statistical calculations. The diameter range, however, was obtained by taking the lowest and highest measured values for a given fiber.

Materials and Methods

Instrumentation

All visible spectral data and illuminate values were obtained using a CRAIC Technologies QDi 1000 microspectrophotometer. Infrared spectroscopy data and analyses were performed on a Perkin Elmer Spectrum Spotlight FT-IR Imaging System. Other physical characteristics of fibers, such as color, diameter, presence/absence of delustrant and/or striation, color distribution, and cross-sectional type were observed via a Nikon Eclipse 6600 POL polarized light microscope at 5X, 10X, and 20X magnifications. Photographs of all fibers were taken using a Q Imaging Micropublisher 5.0 camera and Q Capture software.

Data Collection

For each type of fiber examined, a total of twenty-five visible spectra were obtained. For every five spectra acquired, an *average spectrum* was obtained. The *average* spectra were then processed to determine CIE A and CIE D65 illuminate values for each. Up to three high-intensity peak values were observed and recorded for each of the five *average* spectra. Infrared (IR) spectra for each fiber were obtained in transmission mode and represented an average of thirty-two scans. Polymer type was determined by visual comparison of the acquired spectrum to a series of standard spectra provided by the Trace Evidence Unit of the FBI Laboratory. Physical characteristics of the fibers were observed via polarized light microscopy. For each fiber, the colors present in the fiber, as well as the color distribution (even or variable), were recorded. Observations regarding the presence or absence of delustrant/ pigmentation and/or heavy striations were also recorded. For each fiber type examined, a minimum of three diameter values were measured and recorded; the method of measurement differed depending on the observed cross-section of the fiber. Cross-sectional shape (deltoid, round, Michelin man, and/or trilobal) was also observed and recorded. A complete experimental protocol for acquiring data has been written.

All acquired data, as described above, were entered into the database. The database currently contains a total of seven hundred and sixty-six searchable files, each of which represents a distinct fiber.

Validation I

A total of fifty carpet fiber samples, or *questioned fibers*, were selected at random from those whose characteristics had been previously entered into FACID (i.e. *known fibers*). Data were acquired according to the established protocol. The fifty questioned fibers were searched by activating each of the following parameters: diameter; lambda maximum values; and illuminates CIE A/A*, CIE A/B*, CIE D65/A*, and CIE D65/B*. The number of hits and duplicate files were recorded for each.

Validation II

The fifty questioned fibers described above were re-examined for polymer color, cross-sectional shape, diameter, polymer class, presence/absence of delustrant, presence/absence of heavy striations, and color distribution. For each of the fifty fibers selected, all seven features were searched simultaneously in the database. The number of hits and duplicate files were recorded for each. Of the proposed matches, those files possessing a picture resembling the questioned fiber were recorded.

Validation III

Due to the low hit percentages obtained from validation II, five hundred carpet samples were re-examined for color, cross-sectional shape, diameter, polymer class, presence/absence of delustrant, presence/absence of heavy striations, and color distribution. The database was expanded to include all possible color and diameter variations. For example, if a fiber was originally recorded as white, it was re-examined for possible additional color selections (i.e., tints of light yellow, etc). The new color designations were recorded into the database to ensure a more comprehensive range of color options. An additional forty-one fiber types were examined and added to the database. All of the photographs in the database were double-checked for accuracy.

The fifty questioned fibers were searched simultaneously against the updated seven hundred and sixty-six database files and the hit ratios were recorded. A second search was performed by entering individual variables to determine which variable was problematic.

Validation IV

Another set of fifty automotive carpet fibers were randomly selected from the carpet fiber collection and examined by microspectrophotometry to verify repeatability. The fibers were searched against the seven hundred and sixty-six database files and the hit ratios were recorded.

Results and Discussion

The total number of searchable files was obtained for each of the following fields, or parameters: vehicle year, make, automotive carpet sample location, and polymer class. Automotive carpet samples were obtained from both new and used vehicles whose manufacture dates spanned from 1980 to 2006. The majority of carpet fibers were collected from the passenger area, trunk, and floor mat. All of the automotive carpet fibers examined were found to be of four common polymer classes: nylon 6, nylon 6,6, polyester (PET), and polyolefin.

The results of the first validation in which FACID searches were executed using all nine of the main parameters indicated a low percentage of positive matches (7%). Because the number of positive matches was so few, it was questioned whether inconsistencies within a particular field – or perhaps within a combination of fields – might be responsible.

Consequently, for each of the questioned fibers whose FACID searches did not yield a positive match, comparisons were made between the newly acquired validation data and those data currently stored in the database. From these comparisons, it was determined that data obtained via microspectrophotometry (i.e. illuminate and lambda maximum values) exhibited the greatest number of variations and inconsistencies when compared to the original FACID data. Some diameter values were also inconsistent with their known FACID counterparts, albeit to a lesser extent. It was concluded that additional searches should be executed, in which only a single field would be activated at a given time. Each illuminate value, for example, would be searched individually. Lambda maximum values, as well as diameter values, would be searched in the same manner. The goal of these searches was to deduce which, if any, of the aforementioned parameters were hindering FACID performance.

Searches were performed for all fifty questioned fibers by activating each of the four illuminate fields (CIE A/A*, CIE A/B*, CIE D65/A*, and CIE D65/B*) successively. The results indicated that the CIE D65/A* gave the highest percentage of positive matches (82%), compared to 64% for CIE A/A*, 60% for CIE A/B*, and 60% for CIE D65/B*. Although CIE D65/A* afforded a consistently higher match rate than the other illuminates, it was also less *discriminating*. This phenomenon was evidenced by the average number of net hits returned, 121 (17% of the 719 files present in the database at the time of validation), which was distinctly higher than the number of average hits returned for other illuminates (87, 101, and 105). Practically speaking, the higher the number of hits yielded by a search, the more time an examiner must spend performing comparisons between questioned and known fibers. Therefore, the desire was to have the number of hits returned be as small as possible. Consequently, it was concluded that, while illuminate parameters CIE A/A*, A/B*, and D65/B* were *too sensitive or* *discriminating* (and, therefore, too inconsistent), the CIE D65/A* parameter was *not discriminating enough*.

Searches were also performed by activating any and all lambda maximum values for each of the fifty questioned fibers. Visible spectra for 17 of the 50 fibers displayed no distinct peaks, bringing the total number of database searches to 33**.** Searches by diameter were also performed. In cases where the diameter appeared to vary, several measurements were made and recorded. A corresponding FACID search was executed for each diameter. In five instances, the questioned fiber was judged to be too distorted for an accurate diameter measurement to be made. No FACID search was instigated in these cases. Thus, the total number of searches by diameter was 61. Neither lambda maximum- nor diameter-based FACID searches yielded a high number of positive matches **(**27% and 69%, respectively). The results of the lambda maximum searches were noticeably poor, and the cause of this poor performance was investigated further.

In acquiring original visible data for entry into the database, peak resolution was relatively low for the majority of fibers sampled. With this in mind, it was decided that a *range* of lambda maximum values should be established for each type of fiber. This range would incorporate the standard deviation, and it would serve to combat subjectivity in selecting such values (which are based upon visual inspection of the spectra). Moreover, it was hoped that entering a range into the database, as opposed to a single value, would accommodate inherent instrumental variances, as well.

Nonetheless, only 27% of the lambda maximum values recorded for the validation of questioned fibers were within the known ranges established in the database. Therefore, the data obtained via microspectrophotometry were either too subjective (lambda maximum values) and/or too variable (illuminate values) to be included in further FACID searches. Consequently, it was decided that a second round of validation should take place, in which only the color, cross section, polymer class, delustrant, color distribution, striation, and diameter fields would be searched.

The fifty questioned fiber samples employed in the first round of validation were re-examined for seven characteristics: color, cross-sectional type, diameter, polymer class, presence/absence of delustrant, presence/absence of heavy striation, and color distribution. For this round of validation, samples were first prepared by cutting the questioned fiber into two sections: the first section was rolled onto a diamond cell for analysis via infrared spectroscopy; the remaining section was mounted directly onto a slide for observation under a polarized light microscope. This method of preparation was used to minimize fiber distortion and was employed for all subsequent validations.

For each of the fifty fibers, all seven features were searched simultaneously in the database. As before, in those instances in which exact diameter and/or cross-sectional type were unclear, multiple searches were executed for a given fiber. Thus, the overall number of FACID searches performed in this round of validation totaled 54. In each case, it was determined whether or not the search had yielded a positive match. Moreover, it was also observed whether or not the picture presented in the correct database file did, in fact, resemble the questioned fiber as viewed through the polarized light microscope.

Out of 54 FACID searches, 32 (59%) afforded a positive match. In 28 (88%) of these 32 cases (or 52% of all 54 searches), the photographic representation in the database demonstrated sufficient resemblance to the questioned fiber. Additionally, the efficiency of the 32 aforementioned searches was very high: the average number of proposed matches was approximately 14, or 2% of the 719 searchable files present in the database.

For those questioned fibers whose searches did *not* yield a positive match, comparisons were made to determine which of the validation data were inconsistent with their database counterparts. Results showed that, out of 54 total searches, 22% did not match with regards to fiber color. Other areas of discrepancy included diameter (9% of the total 54), striation (7%), delustrant (4%), cross section (2%), and polymer class (2%). Since the greatest number of discrepancies occurred in the color field, another round of validation was performed. The diameter field demonstrated the next highest number of discrepancies. However, there was a decided improvement from the previous round of validation, in which 73 percent of the measured diameters did not fall within the corresponding ranges in the database Thus, it was concluded that the revised method of sample preparation had, indeed, corrected some of the aforementioned discrepancies .

For the third validation, the fifty questioned fiber samples employed in the second round of validation were re-examined for seven characteristics: color, cross-sectional type, diameter, polymer class, presence/absence of delustrant, presence/absence of heavy striation, and color distribution. For this round of validation, the reassignment of color variations eliminated the poor hit percentages that were observed in the second validation. The percentage of correct hits (i.e. positive matches) obtained was 86, as compared to 59 percent obtained in validation II. In validation III, the most prominent source of a non-match was determined to be the diameter values.

For the fourth validation, a different set of fifty automotive carpet fiber samples were randomly selected and prepared in the method described for validation II. The samples were analyzed via microspectrophotometry to ensure a comprehensive data set. The results of validation IV were consistent with those obtained in validation II. The microspectrophotometric data were too variable to include as a searchable parameter.

Conclusions

Three rounds of validation revealed that calculated color data obtained via microspectrophotometry are too variable to be included as searchable parameters in the forensic automotive carpet fiber database. The determination of fiber color by visual inspection through a microscope is prone to a significant level of subjectivity; to reduce the subjectivity, the protocol was changed. In the new protocol, the fiber examiner will include all colors visibly observed. The third validation proved that the color subjectivity was removed and the other searchable parameters (namely: cross section, diameter, polymer class, presence/absence of delustrant, presence/absence of heavy striations, and color distribution) are still consistent. With the exception of polymer class, data in these areas are both easily obtained and analyzed. The determination of polymer class does require a certain level of training in both the acquisition and interpretation of infrared spectra.

Future Work

A fifth validation is being conducted on fifty new random fibers to ensure the consistency of match percentages. The database search method will be corrected to reduce the diameter variably and a sixth validation will be performed to ensure that the new search method was successful. Additional microspectrophotometry data will be collected in order to incorporate the spectra as a searchable parameter in the database.

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