

MFRC

Midwest Forensics Resource Center

**Research and Development
Program Summary**

November 2009

Acknowledgments

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Midwest Forensics Resource Center (MFRC)

Research and Development Program

Introduction

The mission of the MFRC Research and Development (R&D) Program is to provide technological advances in forensic science for the benefit of our regional partners, as well as the forensic community at large. Key areas of forensic science needs are identified through participation in national meetings in forensic science. Under the sponsorship of the National Institute of Justice (NIJ), the MFRC solicits proposals for the development of practical and useful technology, instrumentation, and methodology that address needs in areas related to forensic science and its application to operational crime laboratories. The MFRC facilitates proposal development by working to establish partnerships between researchers and our regional partners. The MFRC administers a peer review of the proposals and then funds the selected projects at a cost of approximately \$55,000 each, with a 12-month period of performance.

The process for selection of these projects includes the following steps: 1) Drafting of a call for proposals by MFRC staff; 2) Review of the draft call by members of the R&D Advisory Committee; 3) Review and approval of the call by NIJ; 4) Issuance of the call to Iowa State University (ISU), Ames Laboratory, regional partners, and research organizations; 5) Receipt of proposals; 6) Review of proposals by the R&D Advisory Committee; 7) Ranking and selection by MFRC staff using Advisory Committee reviews; 8) Concurrence by NIJ of selected proposals; 9) Notification to proposers; 10) Receipt and review of progress reports by MFRC; 11) Receipt and review of final reports by MFRC, the R&D Advisory Committee, and NIJ; 12) Posting of final reports on the MFRC website.

The decision to fund any specific project is based upon a peer-reviewed call-for-proposal system administered by the MFRC. The reviewers are crime laboratory specialists and scientists who are asked to rate the proposals on four criteria areas including: 1) Relevance to the mission of the MFRC; 2) Technical approach and procedures; 3) Capabilities, teaming, and leveraging; and 4) Dissemination and implementation of research findings. A successful proposal demonstrates knowledge of the background for the research and related work in the field and includes a research methodology with a well-defined plan to implement the technology to benefit our partners at the crime laboratories.

Program Summary Technical Sheets

The following project summaries, while not a complete summary of all research areas, are meant to demonstrate the range of research funded by the MFRC. The project summaries describe the forensic need the projects serve as well as the benefits derived from the technology. The summaries also provide a brief description of the technology and the accomplishments to date. In addition, the collaboration with regional partners and the status of the dissemination of project results and implementation of the product are highlighted. These technical summaries represent the development and implementation of practical and useful technology for crime laboratories that the MFRC hopes to accomplish.

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Abstracts of Funded Projects

CHEMISTRY

• **Analysis of Automotive Clear Coat Paints by Micro-Laser Raman Spectroscopy**

Jay Siegel, School of Science, Indiana University-Purdue University Indianapolis (IUPUI), Indianapolis, IN

This project partially funds the purchase of a Micro-Laser Raman spectrometer to evaluate the feasibility and discriminating power of Raman spectrometry in the characterization and analysis of automotive clear coat paints. This represents one phase of an ongoing project in the analysis of clear coats undertaken by the Forensic and Investigative Sciences Program at IUPUI. The methods used include Micro-laser Raman spectroscopy, Fourier transform infrared spectrophotometry, and UV-visible near infrared spectrophotometry. The Raman phase of the project is conducted in partnership with the Indiana State Police Forensic Science Lab.

• **Application of a Novel Mixed-Mode Reversed-Phase HPLC Column to the Rapid Confirmatory Analysis of Intoxicants and their Hydrophilic Metabolites by LC-MS/MS**

Dwight Stoll, Department of Chemistry, Gustavus Adolphus College, St. Peter, MN

High Performance Liquid Chromatography (HPLC) has become the dominant analytical methodology in forensic drug analysis. Yet, low retention of highly hydrophilic compounds has historically been a significant weakness of reversed-phase HPLC. This project develops rapid (less than six minutes per analysis) reversed-phase HPLC methods for confirmatory analysis of common benzodiazepines and opiates and their major metabolites in blood and urine. Detection of intoxicants is achieved by liquid chromatography tandem mass spectrometry.

• **Application of Chemometric Procedures to Differentiate Ignitable Liquid Residues from Substrate Interferences**

Ruth Waddell-Smith, School of Criminal Justice, Department of Chemistry, Michigan State University, East Lansing, MI

In arson investigations, fire debris is typically extracted and analyzed to determine the presence of ignitable liquid residues. Yet, identification of these residues can be complicated by interferences from substrates. This project targets development of an objective methodology for differentiating ignitable liquids from burned substrates by creating reference collections. The project also demonstrates the potential of statistical and chemometric procedures to associate and differentiate classes of liquids and to differentiate liquids from burned substrate interferences.

• **Comparison of Gas Chromatography-Mass Spectrometry and Liquid Chromatography-Mass Spectrometry for Discrimination of *Salvia divinorum* from Related *Salvia* Species Using Chemometric Procedures**

Victoria McGuffin and Ruth Waddell-Smith, Department of Chemistry, Michigan State University, East Lansing, MI

Salvia divinorum is a hallucinogenic herb that is currently banned in 13 states. The plant is one of nearly 1,000 species of *Salvia*, some of which are culinary herbs and ornamental shrubs. The research develops a method to definitively identify *S. divinorum*. Samples are analyzed by both gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-tandem mass spectrometry (LC-MS/MS) to determine which technique offers the greatest selectivity for the identification of *S. divinorum*. Chemometric procedures are used to identify the most characteristic chemical components that allow differentiation of *S. divinorum* from other *Salvia* species.

- **Evaluation of a Portable Raman Analyzer for Testing Drugs**

Susan Gross, Minnesota Department of Public Safety, Bureau of Criminal Apprehension Forensic Science Laboratory, St. Paul, MN

Large case backlogs can cause slowdowns and delays in the judicial system. Speedy trial demands by defendants are difficult to maintain with these backlogs. This project evaluates a portable drug identification system using laser-based Raman technology to ease some of the backlog problems. The evaluation of the Raman StreetLab® is performed in the laboratory and in the field. By implementing a plan to analyze controlled substances in the field, the laboratory case backlog can be alleviated and the prosecution of drugs cases can continue in a timely manner.

- **The Temporal Fate of Drugs in Decomposing Tissues**

John Wyman, Franklin County Coroner's Office, Columbus, OH

Postmortem tissues that are routinely collected and analyzed and therefore provide the largest comparative database for interpretation are frequently lost in the early stages of putrefaction. When drugs are found in weathered tissues, there is currently little or no information available to help guide the toxicologist, and subsequently the pathologist, in evaluating whether drugs played any significant role in causing death. This study follows the fate of 16 drugs which commonly cause intoxications in seven different tissues collected from decomposing pigs.

- **Ultra-Fast Gradient Elution HPLC as a High Throughput, High Information Content Screening Tool for Drugs of Abuse**

Peter Carr, Department of Chemistry, University of Minnesota, Minneapolis, MN

This project is a continuation of previously-funded work to improve the speed and selectivity of older HPLC methods for screening and identifying drugs of abuse in biological samples. The new project focuses on the effects of instrumental parameters on retention time precision in ultra-fast gradient elution HPLC. The more precise the retention time, the smaller the occurrence of false positives and false negatives.

DIGITAL EVIDENCE

- **A Steganalyzer Package for Forensic Applications**

Jennifer Davidson, Department of Mathematics, Department of Electrical and Computer Engineering, Iowa State University, Ames, IA

The use of steganographic software for hiding information in image files for illicit purposes is becoming more widespread. While steganalysis algorithms abound in academic literature, there are few software programs that address the needs of local police departments who perform computer forensic functions for steganalysis. This project extends the proof-of-concept established on the use of an artificial neural network for wavelet steganalysis in an earlier study. Specific aims are to enhance the capabilities of the software and to make it available for practical use in computer forensics.

PATTERN EVIDENCE

- **A Method for Lifting Bloody Impressions Using a Lifting Strip Containing Titanium Dioxide**

Jessica Zarate, Northville City Police Department, Northville, MI

Bloody impressions are of great importance to the forensic community as they are frequently encountered at crime scenes. Impression evidence in blood cannot always be removed from the crime scene for analysis in a laboratory setting. Many potentially identifiable impressions can only be photographed and not enhanced, thereby complicating the latent print identification process. In an earlier study, a lifting strip containing titanium dioxide was successful in lifting and enhancing bloody fingerprints from several non-porous and semi-porous surfaces of contrasting colors. This study improves upon the methods used to lift bloody palm prints, foot prints, and footwear impressions, in addition to bloody fingerprints from porous, semi-porous, and non-porous surfaces.

• **Application of Face Recognition Technology to Microstamped Cartridge Cases**

Scott Chumbley, Department of Materials Science and Engineering, Iowa State University, Ames Laboratory, Ames, IA and Song Zhang, Department of Mechanical Engineering, Iowa State University, Ames, IA

Microstamping identification has been suggested as a way of providing an objective means to relate guns to fired ammunition. While the method shows promise, questions remain with regard to the durability of the mark. This project determines whether microstamped identifiers can be recognized using a combination of imaging and software recognition methods. Three different quality firearms are obtained and then fired, cleaned, and polished at regular intervals until 1,000 rounds have been fired or the identifier is unreadable. Data is taken using an optical profilometer and analyzed using computers to see if the identifier is recognizable. A corollary study uses metallurgical etching to determine if identifiers purposely removed can be recovered.

• **Discrimination of Dyed Cotton Fibers Based on UV-visible Microspectrophotometry and Multivariate Statistical Analysis**

John Goodpaster, Department of Chemistry and Chemical Biology, Indiana University Purdue University Indianapolis (IUPUI), Indianapolis, IN

Dyed cotton fibers are a common fiber type found in clothing. One of the most popular methods for their analysis is microspectrophotometry. This project analyzes dyed cotton fibers by microspectrophotometry and evaluates the UV-visible spectra using multivariate statistical analyses. This is done to determine the extent to which spectra can be differentiated, identify discriminating spectral features, assess whether spectra can be shared between laboratories, and examine the potential benefits of coordinate transformations and first derivatives.

• **Informing the Judgments of Fingerprint Analysts Using Quality Metric and Statistical Assessment Tools**

Glenn Langenberg, Minnesota Department of Public Safety, Bureau of Criminal Apprehension Forensic Science Laboratory, St. Paul, MN

Fingerprint analysts typically use a number of tools in their decision-making process. This project evaluates the use of two newly developed tools to determine how information regarding the clarity of friction ridge features (quality measurement tool) and the strength of the corresponding friction ridge features (probabilistic tool) inform the judgments of fingerprint analysts. The two tools are also used to determine how information regarding the strength of the corresponding features (when provided by other fingerprint experts) will inform the judgments of the participating analysts. The measured variables for the effect on examiner performance are the accuracy and reproducibility of the conclusions against the ground truth and analyst variation during feature selection.

• **Physical Matching in Trace Evidence: A Validation Study Using Automobile Parts**

Joseph Wermeling, Wisconsin State Crime Laboratory, Madison, WI and Charles Cornett, Department of Chemistry and Engineering Physics, University of Wisconsin-Platteville, Platteville, WI

Physical matches, or fracture matches, constitute an important procedure in trace evidence analysis. In spite of the widespread use of these processes, few validation studies have been conducted to verify what is considered to be an intuitively obvious process. This study validates the physical matching process of questioned automotive parts to a known vehicle in simulated hit-and-run accidents. Laypersons are utilized to test the hypothesis that a given physical match is indeed an intuitive process and to strengthen the position of the forensic examiner who is viewed as more capable in determining physical matches.

• **Three-dimensional Quantification of Characteristics of the Human Dentition**

L. Thomas Johnson, School of Dentistry, Marquette University, Milwaukee, WI

Although DNA can be associated with a human bite, it is not always recovered. Forensic odontologists are under attack for lacking scientific basis for their analyses. This project studies the ability to scientifically quantify the occurrence of special dental characteristics and error rates in the analysis of bitemarks. Using six measurements, a 3-D quantification technique, and 400 samples, a database is created that may provide the criminal justice system with the beginning of a tool and the hard science for objective statement of probability, in either exculpating or incriminating a suspect from patterned injuries caused by human teeth.

Analysis of Automotive Clear Coat Paints by Micro-Laser Raman Spectroscopy

FORENSIC TECHNOLOGY NEED

Within the forensic community, little attention has been paid to date to clear coat paints, i.e., the top layer of automotive paints that contain no pigmentation and serve as a protective film. This may be due in part to the lack of inorganics in clear coats, which are almost always present in color or base coats. Recent advances in micro-laser Raman instrumentation make it easier to obtain high quality spectra of small materials, such as the cross-section of a chip of automotive paint.

TECHNOLOGY DESCRIPTION

Micro-laser Raman spectroscopy is a very powerful sampling and analysis technique that acquires spectra of extremely small areas nondestructively and without touching the sample. Although widely used in many different fields, the technique has seen little application by forensic scientists.

METHODOLOGY

The main objective of this research is to evaluate the effectiveness of micro-laser Raman spectroscopy in discriminating among automobile clear coat paints. A secondary objective is to evaluate micro-laser Raman spectroscopy as part of a scheme to analyze automotive clear coats.

Other techniques that are used in such a scheme are also evaluated. They include Pyrolysis Gas Chromatography-Mass Spectrometry, Fourier Transform Infrared (FTIR) Spectrophotometry, and Ultraviolet (UV)-visible near infrared (NIR) Spectrophotometry.

Specific goals to evaluate the feasibility and discriminating power of Raman spectrometry in

the characterization and analysis of clear coats include:

- Purchase and evaluation of the micro-laser Raman spectrometer
- Optimization of sampling and analysis techniques
- Validation of the techniques and proposed scheme
- Testing of the effectiveness of the scheme to analyze automotive clear coats

ACCOMPLISHMENTS AND ONGOING WORK

A Micro-Laser Raman spectrometer was purchased for the analysis of clear coats. The instrument was defective and replaced by a CRAIC, model CTR-1, 2.5 mW laser at 785 nm with 20x objective.



Figure 1. CRAIC Model CTR-1, 2.5 mW laser at 785 nm with 20x objective

Two hundred eighty-five samples of automobile paint chips with make and model information were obtained (U.S. 200, Australia 50, U.K. 35), and a method for sectioning the chips was developed. The clear coat was peeled off the paint chip, mounted on aluminum foil, and put on the stage of the Raman microscope.

Samples were tested under several thickness conditions (whole chip, 15 μm , 10 μm , and 5 μm), and spectra were obtained using both 50x and 20x objective lenses. Data revealed that spectra obtained from 50x objective were no better than those from the 20x objective, yet they took longer to collect.

MAKES (24)		MODELS (106)			
Acura	Subaru	RSX	Tahoe	Ranger	Cherokee Classic
Beretta	Toyota	GT2	Trailblazer	Ranger LT	Wrangler Voyager
BMW		528i	Z28	Taurus	5E Bonneville
Buick		Century	Crossfire	Taurus LX	Rio G6
Cadillac		LeSabre	Lebaron	Taurus SE	Sedona Grand Am
Chevrolet		Rendezvous	Plymouth	Taurus SEL	Sephia Grand Prix SE
Chrysler		Deville	Sebring	Taurus SES	Sportage Sunbird LE
Dodge		Deville DTS	Explorer	Windstar	3 Trans Am
Ford		SRX	4x4	Jimmy	626 xB
GMC		Uplander	Caravan	Sierra	Protégé Silverado
Honda		1500	Dakota	Sonoma	Cougar Camry
Infiniti		Blazer	Durango	Yukon	Marauder Camry DX
Jeep		Cavalier	Intrepid ES	Accord	Sable Corolla
Kia		Cavalier RS	Ram	Accord LX	Eclipse MR-2
Mazda		Cobalt	Ram 1500	Civic	Galant Rav4 4x4
Mercury		HHR	Ram Charger	Civic EX	Mirage Tacoma
Mitsubishi		Impala	Ram Pick-up	Elantra	Altima Breeze
Nissan		Lumina	Escape x LT	Odyssey	Frontier
Oldsmobile		Monte Carlo	F150	Sonata	Sentra
Plymouth		S Series Blazer	F350	G20	Xtera
Pontiac		Santa Fe 2800	F250 x LT	J30	Aurora
Scion		Sebring 4x4	F250 Super Duty V8	Intrigue	
		Outback Sport 4	Touring Town & Country	Grand Voyager SE	

Table 1. Automobile makes and models

It was also found that 5 μm cross-sections generated the clearest Raman spectra. Based on parameters tested, integration has been narrowed to between 20 and 60 seconds, and number of averages between 5 and 10.

To date, reproducible Raman peaks for any given sample have been obtained, along with consistent results from paint to paint. Yet, the signal to noise ratio has been unacceptably low. It is believed that the laser is underpowered. As a result, the

instrument was sent back to the vendor to retrofit it with a more powerful laser.

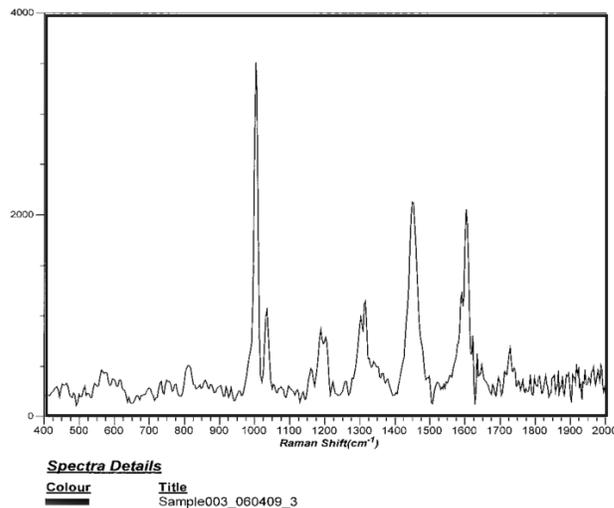


Figure 2. Raman spectra of a 1997 Chevrolet Beretta GT clear coat showing vibrational energy levels.

The new research plan is to evaluate the newly outfitted instrument in the analysis of the clear coats. If successful, Raman spectra will be obtained for all samples, which can then be evaluated by chemometric methods to determine the number of spectra types. Chemometric methods may also reveal correlations among spectral types and make, model, year, and country of origin of the paints.

TECHNOLOGY BENEFITS

Clear coats on automobile paints are very common today. Yet, they have not been analyzed forensically to any degree. This project shows the value of laser Raman spectroscopy when applied to the analysis of trace evidence. Use of the instrument will improve the scientific value of paint evidence and increase the association value of paint evidence to a suspect source.

COLLABORATION

The project is a collaborative effort between Indiana University-Purdue University Indianapolis (IUPUI) Forensic and Investigative Sciences

Program and the Indiana State Police (ISP) Forensic Science Laboratory. Using IUPUI blind samples and samples from previous casework, forensic scientists from the ISP use their own FTIR and UV-visible-NIR instruments, as well as the Raman instrument to evaluate paint chips. ISP also determines the effectiveness of the scheme and of the micro-laser Raman spectrometer in particular, to characterize and compare known and unknown paint chips. Finally, ISP prepares a number of proficiency tests to use for further validation of the Raman technique and of the scheme.

DISSEMINATION

Research findings will be presented at the American Academy of Forensic Science annual meeting. A manuscript will also be prepared for submittal to the *Journal of Forensic Sciences*, while a final technical report on the project and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Siegel, J., Goodpaster, J., Cline, B., Foos, R. “Analysis of Automotive Paint Clear Coats by Raman Spectroscopy.” Presentation made at the Midwest Forensics Resource Center Annual Meeting, July 2009, Indianapolis, IN.

IMPLEMENTATION

Upon completion of the research, ISP will evaluate use of the scheme developed from this project in the analysis of case samples of paint as they come into the laboratory, and as a supplement to their normal analysis protocols. They will also have use of the Raman instrument and microtome for their case work.

CONTACTS

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Application of a Novel Mixed-Mode Reversed-Phase HPLC Column to the Rapid Confirmatory Analysis of Intoxicants and their Hydrophilic Metabolites by LC-MS/MS

FORENSIC TECHNOLOGY NEED

Benzodiazepines are some of the most widely prescribed and abused drugs in Midwestern states. To detect parent drugs and hydrophilic metabolites of certain benzodiazepines, most forensic laboratories currently use Liquid Chromatography-Mass Spectrometry (LC-MS) technology to test for 15 drugs and metabolites in blood and urine samples. However, each run is time-consuming (about 30 minutes) and many of the closely related drugs are not well separated. A method is needed in toxicology laboratories to improve the speed of analysis, detection limits, and to optimize the separation of mixtures of intoxicants.

TECHNOLOGY DESCRIPTION

Low retention of highly hydrophilic compounds has historically been a significant weakness of reversed-phase HPLC (RPLC), which is the most common mode of liquid chromatography in use today. This weakness has prompted the development of several approaches to increase retention, including the use of conventional cation-exchange materials, ion-pairing reagents as additives in mobile phases used for RPLC, and the more recent development of Hydrophilic Interaction Chromatography (HILIC). This project evaluates the application of a novel mixed-mode RPLC column.

METHODOLOGY

Specific objectives of the project are to:

- Compare the retention of 16 benzodiazepines and nine opiates on two LC-MS HPLC columns; the novel carboxylated Hyper-Crosslinked-C8 (Mixed-Mode-C8)

column and a conventional reversed-phase (StableBond-C18) column

- Compare the LC-MS/MS detection limits for the 25 compounds using the novel and conventional reverse phase columns
- Adjust the operational parameters (i.e., column length, particle diameter, flow rate, gradient elution conditions, temperature, etc.) to optimize the throughput of the assays
- Evaluate the sensitivity and specificity of the LC-MS/MS assays by analyzing blood and urine extracts and comparing the results with data collected by the MN Bureau of Criminal Apprehension using LC or Gas Chromatography-Mass Spectrometry (GC-MS) for the target compounds
- Evaluate false negative and false positive rates for the new method

ACCOMPLISHMENTS AND ONGOING WORK

This is a newly funded project. Preliminary work indicates that separation of highly hydrophilic

Compounds	Relative Retention (t_R/t_0)	
	SB-C18	CO ₂ --HC-C ₈
Hydrocodone	7.7	8.1
Pseudoephedrine	3.1	6.2
7-Aminoclonazepam	2.6	2.5
7-Aminoflunitrazepam	3.4	3.3
Clonazepam	10.1	7.7
Flunitrazepam	11.9	10.0

Table 1. Relative retention times of six regulated intoxicants on SB-C18 and CO₂--HC-C8 phases

compounds with a novel hydrophobic cation exchange phase is possible, and that the novel phase will be useful in achieving the stated objectives.

TECHNOLOGY BENEFITS

By developing rapid HPLC methods for confirmatory analysis of benzodiazepines, opiates and their metabolites, this work will greatly improve the screening of drugs of abuse and the throughput in toxicology laboratories.

COLLABORATION

This project is a collaborative effort among Gustavus Adolphus College, the Minnesota Bureau of Criminal Apprehension (BCA) Forensic Science Laboratory, and the University of Minnesota. The primary role of the Minnesota BCA is to provide counsel and extracts of blood and urine samples. The University of Minnesota provides the HPLC columns and guidance for their use in the project.

DISSEMINATION

Research findings and results will be presented at conferences (e.g., the Society of Forensic Toxicologists, the Pittsburgh Conference) and at meetings of the American Chemical Society. A manuscript will also be submitted to the *Journal of Analytical Toxicology* and the *Journal of Chromatography*. A final technical report will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new research project with no publications or presentations to date.

IMPLEMENTATION

The Minnesota BCA has expressed interest in possible implementation of the technology should the project be successful. To achieve this, the methods developed will be evaluated in accordance

with the Minnesota BCA's validation plan for toxicology chromatographic methods. The outcome of the validation process, along with factors such as throughput, ease of use, and improvements over existing methods, will determine the feasibility of implementation by the Minnesota BCA lab, and other laboratories as well.

CONTACTS

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Application of Chemometric Procedures to Differentiate Ignitable Liquid Residues from Substrate Interferences

FORENSIC TECHNOLOGY NEED

In arson investigations, fire debris is typically extracted and analyzed to determine the presence of ignitable liquid residues (ILR). However, identification of ILRs can be complicated by interference from substrates, including inherent hydrocarbons and pyrolysis products.

TECHNOLOGY DESCRIPTION

In this project, ignitable liquids, evaporated liquids, and burned household substrates are analyzed by gas chromatography mass spectrometry (GC-MS) to generate reference collections of each. The potential of chemometric procedures to differentiate ignitable liquids from burned substances is investigated. To establish an objective methodology for the identification of ILRs in the presence of burned substrate interferences.

METHODOLOGY

Specific goals of the research are to:

- Create reference collections of neat and evaporated ignitable liquids
- Create reference collections of burned household substrates
- Optimize data pre-treatment procedures for statistical and chemometric analyses
- Assess correlations among neat ignitable liquids, evaporated liquids, and burned substrates using Pearson Product Moment Correlation (PPMC) coefficients
- Assess association and discrimination of neat ignitable liquids, evaporated liquids, and

burned substrates using principal component analysis (PCA)

ACCOMPLISHMENTS AND ONGOING WORK

Reference collections were created of 18 liquids from each of the six different classes (as defined by the American Society for Testing of Materials). All liquids were purchased from local stores and internet sources. In addition, local sources were used to create reference collections of burned and unburned substrates (nylon carpet, upholstery, glossy magazine paper, and denim).

Brand Name/ Manufacturer	Type of Ignitable Liquid	ASTM Class
Meijer	Gasoline	Gasoline
Shell	Gasoline	Gasoline
Mobil	E85 Gasoline	Gasoline
Goo Gone	Candle wax lifter	Alkane
Lamplight	Ultra-pure paraffin lamp oil	Alkane
Northern Lights	Ultra-pure lamp fuel	Alkane
Goof Off	Ultimate remover	Aromatic
Recochem	Lacquer thinner	Aromatic
Ortho	Insect spray	Aromatic
Sunnyside	Odorless paint thinner	Isoparaffinic
Crown	Odorless paint thinner	Isoparaffinic
Scotch Guard	Fabric and upholstery protector	Isoparaffinic
Tiki	Torch fuel	Naphthalenic paraffinic
Medallion	Lamp oil	Naphthalenic paraffinic
Pennzoil	Marine fuel cleaner and stabilizer	Naphthalenic paraffinic
STP	Fuel injector and carburetor	Petroleum distillate
Meijer	Kerosene	Petroleum distillate
Sunoco	Diesel	Petroleum distillate

Table 1. List of 18 ignitable liquids included in reference collections

The liquids were diluted 350:1 in dichloromethane (spectrophotometric grade) prior to analysis, with the exception of gasoline, diesel and kerosene, which were diluted 10:1 in dichloromethane. Each liquid was analyzed in triplicate by GC-MS. Chromatograms obtained of the ignitable liquids show characteristic compounds and compound classes, while the chromatograms of the burned and unburned substrates indicate that there are compounds that can interfere with the detection and identification of ignitable liquid residue on the substrate. It was also found that the burning process introduced degradation products that can further complicate detection and identification of the ignitable liquid.

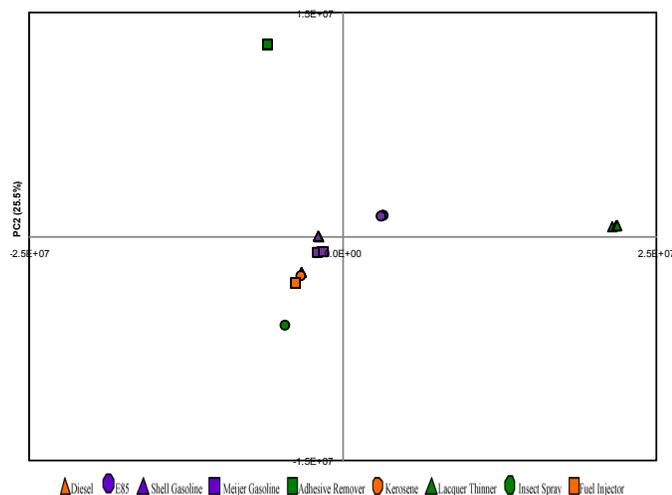


Figure 1. Scores plot based on the TIC for nine ignitable liquids in the aromatic subset

Using the 18 ignitable liquids as a data set, a range of warp and segment sizes for the retention time alignment were considered. Using a warp of 3 and a segment size of 25, misalignments were found for the malathion peak and for the C2-alkylbenzenes and C3-alkylbenzenes.

Reducing the warp size to 1 (segment size 25) slightly improved alignment of the C2-alkylbenzenes and C3-alkylbenzenes, but the malathion peak remained poorly aligned. Optimal alignment was observed using a warp size of 1 with a segment size of 45.

Subjecting the data sets obtained to statistical analyses to investigate association and discrimination of liquids and burned substrates based on total ion chromatograms (TIC) and extracted ion profiles (EIP) revealed two things.

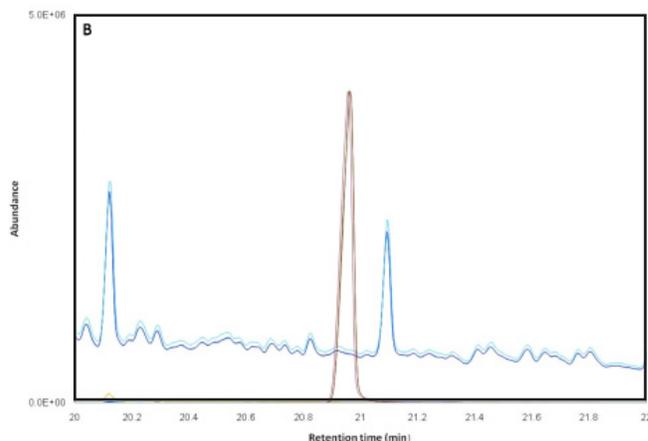


Figure 2. Acceptable alignment of malathion peak, using a warp of 1 and a segment size of 45 (retention time 20.95 minutes)

First, for both the alkane and aromatic subsets, there was little additional discrimination afforded among the liquid classes when PCA was conducted based on the EIPs rather than the TICs.

Second, the combination of PCA and PPMC coefficients proved invaluable to discriminate burned matrices from the neat liquids, despite close positioning in the score plots. The next stage of the research focuses on association of the evaporated liquids to the corresponding neat liquid with discrimination in different classes.

TECHNOLOGY BENEFITS

Reference collections for burned substrates are not currently available. The creation of a reference collection of burned household items will improve forensic arson investigations. By developing mathematical procedures, subjectivity associated with the comparison of chromatograms will also be improved and objective distinction of ignitable liquids from substrate interferences increased. This

will reduce the risk of false positive identifications of liquids in fire debris.

COLLABORATION

This is a collaborative effort between the Michigan State University (MSU) and the Michigan State Police (MSP). Troy Ernst of the MSP Grand Rapids Trace Evidence Unit serves as a consultant on the development of the methodologies and their implications to forensic crime laboratories.

DISSEMINATION

The findings of the research have been presented at a professional meeting and were also presented and discussed with potential users at national meetings, such as at the Joint Meeting of the Midwestern, Mid-Atlantic, Southern, and Southwestern Associations of Forensic Scientists. A manuscript on the findings of the research, discussing the development of reference collections, has been submitted to the *Journal of Forensic Sciences*. Upon completion of the research, a final technical report on the research and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Baerncopf, J., McGuffin, V., Waddell-Smith, R., “Discrimination of Ignitable Liquids from Burned Matrix Interferences Using Chemometric Procedures.” Presentation made at the American Academy of Forensic Sciences 61st Annual Meeting, February 2009, Denver, CO.
- Baerncopf, J., McGuffin, V., Waddell-Smith, R., “Discrimination of Ignitable Liquids from Matrix Interferences Using Chemometric Procedures.” Manuscript submitted for publication in the *Journal of Forensic Sciences*.

•McIlroy, J., “Statistical and Chemometric Analysis of Ignitable Liquids for Arson Investigations.” Presentation made to the Illinois State Police, March 2009, Chicago, IL.

- Van De Mark, T., Bodnar, M., McGuffin, V., Waddell-Smith, R., “Association of Evaporated Ignitable Liquids to their Neat Counterparts Using Pearson Product Moment Correlation Coefficients and Principal Analysis.” Poster presentation at the Joint Meeting of the Midwestern, MidAtlantic, Southern, and Southeastern Associations of Forensic Scientists, October 2009, Orlando, FL.
- Waddell-Smith, R., “Application of Chemometric Procedures to Differentiate Ignitable Liquid Residues from Substrate Interferences for Arson Investigations.” Discussion session at the Joint Meeting of the Midwestern, MidAtlantic, Southern, and Southeastern Associations of Forensic Scientists, October 2009, Orlando, FL.

IMPLEMENTATION

The researchers are attempting to establish proof-of-concept. If successful, the PIs may seek additional funding from NIJ to continue the research.

Discussions are currently being held with interested parties and potential users to obtain feedback on the practicality of the approach and usefulness of the data generated. Upon completion of the research, a DVD of reference collections generated will be made available to the forensic community.

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Comparison of Gas Chromatography-Mass Spectrometry and Liquid Chromatography-Mass Spectrometry for Discrimination of *Salvia divinorum* from Related *Salvia* Species Using Chemometric Procedures

FORENSIC TECHNOLOGY NEED

Salvia divinorum is a hallucinogenic herb which is currently banned in 13 states. With legislation pending in several others, there is a need to identify *S. divinorum* from other *salvia* species using chromatographic techniques and chemometric procedures. This project develops a method to differentiate *S. divinorum* from the nearly 1,000 species of *Salvia* that are currently known, some of which are culinary herbs and ornamental shrubs.

TECHNOLOGY DESCRIPTION

Previous research investigated the selectivity of different organic solvents for extraction of salvinorin A (the active hallucinogenic component) from dried leaves of *S. divinorum* and *S. officinalis*. Methyl chloride appeared the most promising, extracting the greatest number of components and the highest abundance of salvinorin A in *S. divinorum*. This research builds upon the preliminary work.

METHODOLOGY

The objective of the project is to develop an analytical methodology for the definitive identification of *Salvia divinorum* with differentiation from other *Salvia* species.

This is accomplished by:

- Investigating and comparing three different extraction procedures for components of interest (manual agitation, rotary agitation, and sonication)

- Investigating the selectivity offered by Gas Chromatography-Mass Spectrometry (GC-MS) in creating a chemical fingerprint of *S. divinorum*
- Investigating the selectivity offered by Liquid Chromatography-Mass Spectrometry (LC-MS/MS) in creating a chemical fingerprint of *S. divinorum*
- Comparing chemical markers and using chemometric procedures to identify the most characteristic chemical components that allow differentiation of *S. divinorum* from other *Salvia* species

ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that has not yet started work.

TECHNOLOGY BENEFITS

This research establishes proof-of-concept and can help in the development of optimized and validated procedures for the analysis and identification of *Salvia divinorum*. In doing so, the method could eventually be implemented in states that have already regulated the plant and be made available to forensic laboratories should *S. divinorum* or its active ingredient, salvinorin A, become federally controlled in the United States.

COLLABORATION

The project is a collaborative effort between Michigan State University and the Michigan State Police (MSP). The MSP will provide counsel for analysis.

DISSEMINATION

This work will be disseminated at the American Academy of Forensic Sciences Annual Meeting and presented at one of the MSP laboratories to which interested drug analysts will be invited. If warranted, a manuscript will be submitted for publication in the *Journal of Forensic Sciences*. A final technical report will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new research project with no publications or presentations to date.

IMPLEMENTATION

As the method develops, graduate students from the MSU Forensic Science Program will help train MSP drug analysts in implementing the method in MSP laboratories.

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Evaluation of a Portable Raman Analyzer for Testing Drugs

FORENSIC TECHNOLOGY NEED

Numerous liquid and solid samples are submitted for analysis to crime laboratories annually. These analyses are very time consuming and often lead to large case backlogs which typically cause delays in the judicial system. Speedy trial demands by defendants are subsequently difficult to maintain.

This project attempts to ease some of the backlog problems by evaluating a portable drug identification system that uses laser-based technology. The objective of the project is to evaluate a portable Raman unit for screening and identifying controlled substances, both in the laboratory and in the field.

TECHNOLOGY DESCRIPTION

The system evaluates the FirstDefender, manufactured by Ahura Scientific. The instrument utilizes Raman spectroscopy, which is similar to infrared spectroscopy in that it analyzes scattered light. The advantage of Raman spectroscopy is that glass or plastic does not interfere with the scattering.



Figure 1. Portable raman analyzer manufactured by Ahura Scientific

The FirstDefender is a portable, handheld instrument designed for rapid identification of solid and liquid samples. The small size and non-destructive nature of Raman make it a potentially useful product in the hands of law enforcement personnel as well as crime laboratory forensic scientists.

METHODOLOGY

To achieve the objective, the FirstDefender is used to compare street drugs to known standards, analyze scanning capabilities through glass and plastic, and test the ability of the system to quantify methamphetamine and cocaine.

Specific activities include:

- Train instrument users in operation and use of the handheld analyzer
- Validate the instrument for reproducibility and reliability
- Evaluate and determine the detection limit sensitivity
- Build a library of controlled substances in the handheld analyzer
- Evaluate the system's use in producing positive identification of street drugs
- Compare street drug analyses to results produced on a Gas Chromatography-Mass Spectrometry (GC-MS)

ACCOMPLISHMENTS AND ONGOING WORK

Ahura Scientific provided training in operation and use of the analyzer. They also provided guidance on how to run the samples and incorporate them

into a searchable Bureau of Criminal Apprehension (BCA) library.

Instrument validation was checked using a polystyrene plug that came with the instrument. The FirstDefender was validated for reproducibility by running a sample of cocaine standard multiple times while it was checked for reliability by comparing the standard analyzed to known literature spectra. The sensitivity and detection limits were also evaluated using known standards. A subsequent library was then built using drug standards, electronic balances, and glass vials.

In instrument comparison trials, results varied with the use of the FirstDefender by both agents and scientists. Using both FirstDefender and GC-MS in analyzing mixtures of methamphetamine/dimethyl sulfone, results coincided in about 85% of the case samples. In the other 15%, no matches were found or the sample was misidentified.

In sensitivity detection limit experiments, samples of cocaine/procaine were analyzed to see at what concentration the instrument could detect cocaine. Results showed that the FirstDefender could not detect cocaine at concentrations below 50%.

After running a total of 200 drug standards and glass vial samples, several mixtures of methamphetamine/dimethyl sulfone and cocaine/procaine of varying concentrations were added to the library. Unknowns were then tested against the library to see if the instrument could quantify samples.

Results of the testing varied. At low or high concentrations of methamphetamine, the instrument produced “ballpark” results. That is, a 90% methamphetamine sample produced a library match for 90% methamphetamine. Anything between 70% and 30% produced varying results. For cocaine, the instrument could detect concentrations accurately.

TECHNOLOGY BENEFITS

A screening test (non-confirmatory) is often all that is needed for court administrators to begin the process of prosecuting individuals involved with controlled substances. Having a portable Raman unit in the field can expedite this process. Law enforcement personnel trained on the correct use of the instrument can obtain results within minutes, thereby making it possible to analyze samples while the suspect is still in custody. Portable Raman analyzers have the potential to become as common as the Breath Analyzer used to determine blood alcohol levels.

COLLABORATION

This project is a collaborative effort among the Minnesota Bureau of Criminal Apprehension and Minnesota law enforcement agencies.

The laboratory portion of this project takes place in the Drug Chemistry Section of the Minnesota Bureau of Criminal Apprehension (BCA) in St. Paul, MN. Available drug standards were utilized to analyze known samples, and some previously analyzed “street” samples were also used.

The field portion of the project takes place in the Law Enforcement Center (LEC) in Rochester, MN. The LEC houses various law enforcement agencies including field offices for the BCA, the Gang Strike Force, the Southeast Minnesota Drug Task Force, the Rochester Police Department, and the Olmsted County Sheriff’s Office.

DISSEMINATION

Research findings were presented to forensic scientists and law enforcement personnel, and were also shared with Ahura. Results were published in the Midwestern Association of Forensic Scientists (MAFS) newsletter and in a final technical report, which is posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Gross, S., “First Defender Grant Project.” Presentation to BCA agents, January 2008, St. Paul, MN.
- Gross, S., “First Defender Grant Project.” Presentation to Minnesota law enforcement agents, February 2008, St. Paul, MN.
- Engebretson, A., Patterson, M., Radthke, J., “Validation Study for First Defender.” Oral presentation at the 37th Annual Midwestern Association of Forensic Scientists Meeting, October 2008, Des Moines, IA.
- Radthke, J. and Patterson, M., “Validation Study for First Defender.” Published in the Midwestern Association of Forensic Scientists Newsletter, April 2009, Vol. 38, Nr. 2, pp. 31-47.

IMPLEMENTATION

As part of the experimental design, the FirstDefender was used by special agents in the Rochester area to produce preliminary positive identification of street drugs. Results varied and it was decided that additional research and testing is needed to better quantify samples. The BCA is currently in the process of identifying a narcotics investigator interested in collecting additional field test data. If successful, the instrument may have a place in the field, especially if used in conjunction with chemical field tests already in place.

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The Temporal Fate of Drugs in Decomposing Tissues*

FORENSIC TECHNOLOGY NEED

Interpreting drug concentrations in decomposed remains is difficult. Postmortem tissues that are routinely collected and analyzed for interpretation (blood, urine, vitreous humor) are frequently lost in the early stages of putrefaction. When drugs are found in weathered tissues, there is currently little information available to help guide the toxicologist in evaluating if drugs played any significant role in causing the death.

TECHNOLOGY DESCRIPTION

The lack of information about the fate of drugs in decomposing tissues is understandable given that postmortem studies in humans are not realistic. This study monitors the postmortem fate of drugs over time in different tissues of the domesticated pig (*Sus scrofa*).

Pigs are selected because their size and physiology are comparable to humans, allowing high-level dosing and sequential sampling of multiple tissues. Specifically, their digestive and cardiovascular physiology allow for drug absorption and distribution that closely mimic those of humans.

METHODOLOGY

The objective of the project is to obtain the following information:

- How long drugs and metabolites persist in tissues at detectable levels
- How the weathering of tissues alters the concentration of drugs
- Which are the most important tissues to collect

- Which collection sites are most useful for detecting drug exposure and interpreting results

To achieve this, the concentration of 16 drugs in tissue from decomposing pigs weighing 120-150 pounds is monitored in blood, brain, liver, kidney, muscle, maggots, and soil during one week. Drugs monitored include morphine, amitriptyline, citalopram, diazepam, methadone, fluoxetine, doxepin, acetaminophen, oxycodone, diphenhydramine, venlafaxine, carisoprodol, verapamil, zolpidem, and propoxyphene.



Figure 1. Transfer of pigs to site

Pigs are divided into groups (n=5) with each group receiving four drugs. Drug cocktails, prepared from pills (capsules or tablets) are obtained as pharmaceutical formulations. Sacrifice of pigs (using intracardiac pentobarbital) is four hours after dosing (gavage) to allow for partial gastric emptying, absorption of drugs, tissue distribution, and incomplete metabolism.

Tissue collection times are approximately four hours after dosing, and then at 4, 24, 48, 96, and 168 hours. Samples are frozen until assay. Tissue specimens are thawed, an aliquot removed and

*Approval to perform animal research was obtained from The Ohio State University Institutional Laboratory Animal Care and Use Committee

(except for blood) weighed and homogenized. Internal standards (SKF525A, hexobarbital, and/or nalorphine) are added to blood and homogenates prior to extraction.

Drugs are extracted from tissues using Solid Phase Extraction (SPE) columns. Analysis of basic/acid/neutral drugs is performed using Gas Chromatography-Mass Spectrometry (GC-MS) analysis. Morphine is derivatized with heptafluorobutyric anhydride and assayed by GC-MS Selective Ion Monitoring (SIM), while acetaminophen is analyzed by Fluorescence Polarization Immunoassay (FPIA).

ACCOMPLISHMENTS AND ONGOING WORK

Twenty-four pigs were obtained for testing. Nine were sacrificed in the initial attempt, five for testing and four as controls. Control pigs were included to determine whether total organ weight changed as a result of necropsy.

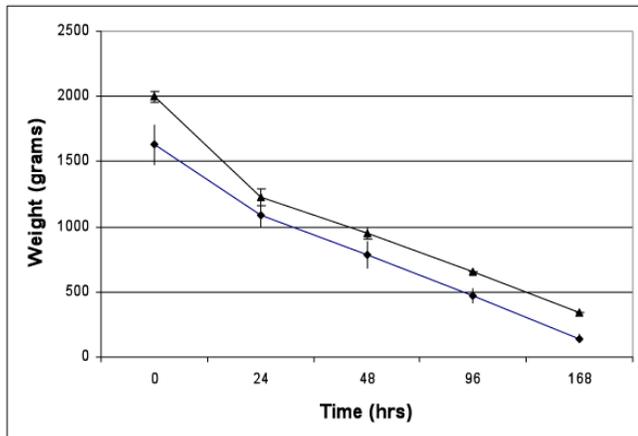


Figure 2. Loss of liver weight over time in necropsied --◆-- pigs; n=5 and non-necropsied (control) --▲-- pigs; n=2 for 0-48 hours.

The initial attempt to dose the pigs through their food was unsatisfactory. The amount of drugs consumed was of very low levels and varied from animal to animal. It was decided that drugs needed to be administered by gavage as slurry. Dosing of pigs allowed them to live four hours after gavage. It

was also found that the rate of decomposition was much faster than anticipated. Brain and kidneys were not available after 48 hours, while muscle and liver persisted for one week. Drugs in soil were detected as early as one week and bone marrow was found to be an unsatisfactory specimen for testing and measuring. The concentrations of drugs analyzed typically increased with the state of decomposition. The increase in concentration was not the same for all drugs, with the concentration of drugs in liver increasing to a much greater extent than those in muscle.

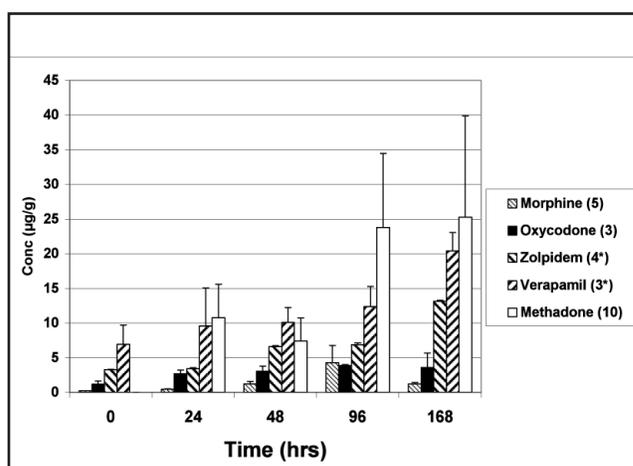


Figure 3. Average temporal increase in morphine, oxycodone, zolpidem, verapamil, and methadone in decomposing liver. Error bars represent SEM and statistical significance is indicated by *

The fact that drug concentrations increased dramatically in decomposing tissues may cause coroners or medical examiners to issue the mistaken diagnosis of drug overdose, either accidental or suicidal. The results of the study clearly show that at autopsy, and considered in isolation, high levels of drugs in decomposed bodies can neither support nor negate an overdose as the cause of death.

TECHNOLOGY BENEFITS

This investigation provides important insights into the fate of drugs in various tissues over an extended period of decay. The information gained allows pathologists, toxicologists, and criminologists to

accurately interpret case results and determine cause of death and fate of the victims.

COLLABORATION

This is a collaborative effort between the Franklin County Coroner's Office (FCCO) and The Ohio State University (OSU). Pathologists from both institutions assisted in the collection of tissues. Toxicology was performed at the FCCO, while a biostatistician performed statistical analysis of results at OSU. Approval to perform animal research was obtained at OSU (the site of decomposition was leased from OSU).

DISSEMINATION

The results of this study were presented at a number of national and international coroner's and medical examiner's conferences, forensic toxicology meetings, and at the Midwest Forensics Resource Center Annual Meeting. A manuscript has been submitted to the *Journal of Forensic Sciences*. A final technical report on the study and its findings is posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Wyman, J., "The Toxicology of Suicide." Presentation made at the Society for the Scientific Detection of Crime, March 2008, Columbus, OH.
- Wyman, J., "The Toxicology of Suicide." Presentation made at the International Association of Coroners and Medical Examiners, June 2008, Cincinnati, OH.
- Wyman, J., Dean, D., Yinger, R., Simmons, A., Brobst, D., Bissel, M., Silveira, F., Shott, R., Ohr, J., Tatarek, N., and Lewis, B., "The Temporal Fate of Drugs in Decomposing Porcine Tissue." Presentation made at the Society of Forensic Toxicologists (SOFT) conference, October 2008, Phoenix, AZ.

- Wyman, J., "The Temporal Fate of Drugs in Decomposing Tissues." Presentation made at the Midwest Forensics Resource Center Annual Meeting, July 2009, Indianapolis, IN.
- Wyman, J., Dean, D., Yinger, R., Simmons, A., Brobst, D., Bissel, M., Silveira, F., Kelly, N., Shott, R., Ohr, J., Howard, R., and Lewis, B., "The Temporal Fate of Drugs in Decomposing Porcine Tissue." Manuscript submitted to the *Journal of Forensic Sciences*.

IMPLEMENTATION

As a result of this work, the FCCO in Columbus, OH no longer tries to interpret therapeutic, toxic, and lethal drug concentrations in decomposing bodies. A medical examiner from California also expressed an interest in the research results for possible application.

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Ultra-Fast Gradient Elution HPLC as a High Throughput, High Information Content Screening Tool for Drugs of Abuse

FORENSIC TECHNOLOGY NEED

Gradient elution high performance liquid chromatography (HPLC) with diode array detection is a common method used for screening and identifying drugs of abuse in biological samples. Although the technique has tremendous chemical selectivity and can produce precise retention time data under well-controlled conditions, the technology is quite slow, requiring 20-30 minutes per run. As the sample load in forensic laboratories continues to increase, using HPLC techniques to deliver analytical sample judgment in a timely manner is becoming more difficult.

TECHNOLOGY DESCRIPTION

In a previously-funded project, ultra-fast gradient elution reversed-phase HPLC with diode array detection was developed as a fast tool for screening samples of regulated intoxicants. Through a combination of column chemical selectivity and chemometric analysis of the spectrochromatograms, both the speed and selectivity of older HPLC methods could be significantly improved. This project focuses on the effects of instrumental parameters on retention time precision in ultra-fast gradient elution HPLC. The more precise the retention time, the smaller the occurrence of false positives and false negatives.

METHODOLOGY

The precision of retention time in gradient elution HPLC is significant for compound identification and setting peak integration time windows. Because of this, precision of retention is an important characteristic for quantitative measurements in HPLC. Highly imprecise retention times are an indication of instrumental problems in the liquid chromatography system.

In this project, the effect of four instrumental parameters is investigated for three different groups of solutes. The first is a group of 14 of the 16 standard solutes chosen by Snyder and Dolan to characterize some 371 commercially available reversed phases. The second is a set of 18 common basic pharmaceuticals, and the third is a set of 22 simple derivatives of benzene which have been used extensively in previously-funded projects to study retention times in reversed-phase liquid chromatography by the linear solvation energy approach.

Based on measured characteristics of the three groups of solutes, retention times can be computed under a wide range of experimental conditions. To achieve this, the effect of small changes in the individual operational variables (temperature, mobile phase, gradient time, and flow rate) on the precision in retention time is investigated. Temperature is chosen because thermal effects cause baseline noise and problems in retention repeatability. Mobile phase, gradient time, and flow rate are selected as any disturbance in mobile phase composition; gradient time or flow rate can have a direct impact on the "gradient steepness" and change the retention time. The flow rate also influences the temperature control, which in turn affects retention precision.

ACCOMPLISHMENTS AND ONGOING WORK

The effect of fluctuations in four instrumental parameters in gradient elution liquid chromatography on retention precision was investigated for the three groups of compounds. It was found that a change in any of the parameters changes the absolute retention time.

Additionally, it was found that early eluting compounds are generally more sensitive to changes

in temperature, initial mobile phase, and flow rate, whereas late eluting peaks respond more to changes in final mobile phase and gradient time.

The effect of changes of the instrument variables on retention time precision varied considerably with gradient time. Absolute changes in retention time were generally larger at longer gradient times. Within the three groups of solutes examined, basic drugs showed less sensitivity to temperature changes than simple, relatively less polar solutes.

Column temperature could be varied for the basic drugs by as much as 2.4° Celsius without changing their retention times by more than 1%. On the other hand, low polar solutes tolerated changes in difference between the “repeatable” and “full” equilibrium states of column re-equilibration.

It was concluded that temperature control is by far the most important variable influencing the absolute retention reproducibility. With regard to system needs, it is also more poorly controlled than any of the other operational variables.

Instrument manufacturers should therefore strive to improve temperature control to about 0.1-0.2° Celsius on a day-to-day basis.

TECHNOLOGY BENEFITS

This work will vastly improve the screening for drugs in blood, urine, and other tissue samples. It will also significantly impact forensic toxicology.

COLLABORATION

This project is a collaborative effort between the University of Minnesota and the Minnesota Bureau of Criminal Apprehension (BCA). The collaboration consists of forensic scientists from the BCA Forensic Science Laboratory visiting the Principal Investigator’s (PI) laboratory and attending group meetings. In return, the PI and his

group visits the BCA to work on specific project aspects.

DISSEMINATION

Information and data from the project are presented at professional meetings and are at national conferences, including the American Academy of Forensic Science and the HPLC Symposium.

Upon completion of the project, a manuscript will also be submitted to journals like the *Journal of Chromatography A* and the *Journal of Forensic Sciences*. A final technical report on the project and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Beyaz, A. and Carr, P. “Instrument Parameters Controlling Retention Precision in Gradient Elution Reverse-Phase Liquid Chromatography.” Presented at the Minnesota Chromatography Forum, May 2009, Minneapolis, MN.

IMPLEMENTATION

After demonstrating predictive capabilities of the technology, the methodology will be transferred to the BCA for use on actual toxicology samples. Results will be compared to current procedures to establish performance statistics.

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A Steganalyzer Package for Forensic Applications

FORENSIC TECHNOLOGY NEED

The use of steganographic software for hiding information in image files is becoming more widespread. While steganalysis algorithms abound in the academic literature, few address the needs of law enforcement agencies performing computer forensic steganalysis. Those currently available are very expensive and require extensive training of forensic personnel. The goal of this project is to develop a software package that allows crime laboratory personnel to scan computers for Joint Photographic Experts Group (JPEG) image steganalysis.

TECHNOLOGY DESCRIPTION

The research described here builds upon the findings of a previously-funded project which demonstrated proof-of-concept on the use of an artificial neural network for wavelet steganalysis. ANNTS, as the software program was called, simply scanned an image for hidden content. It exhibited good steganalysis detection rates and ease of use by non-specialists.

METHODOLOGY

Specific goals for this project are to:

- Expand the capabilities of ANNTS by enabling the software to inspect multiple images. The current capability of the software is to scan a single image. By modifying the code, a file folder of image data can be inspected and the results written to a file. Similarly, by modifying the software user interface, the meaning of labels written on screen can become clearer.
- Add two more targeted detection techniques. ANNTS currently utilizes four techniques

and this project adds two more to scan for JPEG embedded images. The new techniques are selected based on their potential use for illegal criminal activity and interest by crime laboratory forensic scientists.

- Develop a “blind” (general) detection technique based on the *dual-tree complex wavelet transform* (DT-CWT) and a *partially ordered Markov model* (POMM) for image data.
- Add detection schemes to the Graphical User Interface (GUI) of ANNTS, and rewrite the software code in Java to make the steganalyzer useful and available in a cross-platform package to its users.

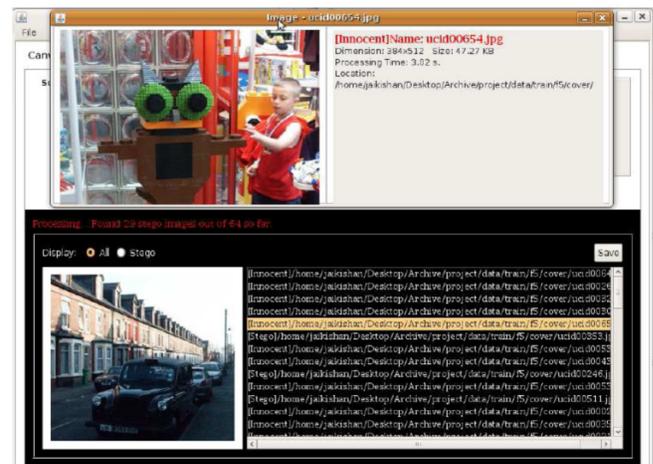


Figure 1. Graphical user interface with detailed information

ACCOMPLISHMENTS AND ONGOING WORK

The ANNTS software was modified to inspect multiple images. A collection of file folder locations were scanned automatically, as were websites specified by URL. The user can now specify the source of images (machine or web address) and the software steganalyzes JPEG images against the

steganographic algorithms present in the system. The software then displays the detailed processing information in real time, as well as the image for visual inspection.

Two stenographic methods were added to scan for JPEG embedded images: S-tools and JPHide & Seek. Both were chosen due to their potential use for illegal criminal activity and interest by crime laboratory forensic scientists. S-tools was later removed due to its impractical nature for submitting batch jobs, as it currently can only be run on a single image. Five different stenographic methods were analyzed; JSteg, JPHide & Seek, OutGuess, F5, and StegHide.

To develop the steganalyzer, a statistical model called the *partially ordered Markov model* (POMM) was examined. POMMs are a subclass of Markov random field models that have been used successfully for texture analysis and pattern recognition. Three to five POMMs were developed and their potential for steg detection is currently being investigated.

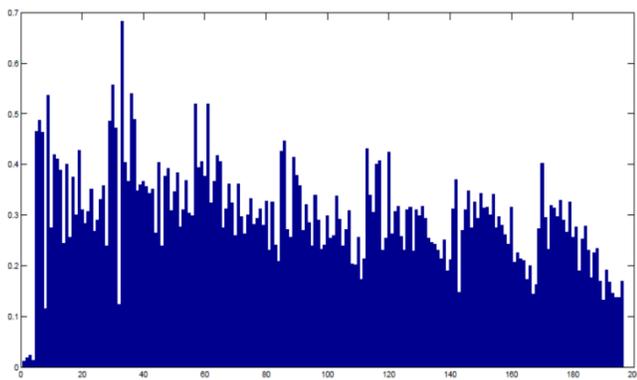


Figure 2. Mahalanobis distance graph for individual features for POMM

The remaining work will concentrate on developing a POMM model for the steganalyzer, incorporating it into the software code, and rewriting the software code in Java to make it available in a public setting.

TECHNOLOGY BENEFITS

The research will provide crime laboratories with a software package that addresses basic steganography needs for forensic applications. Currently, few crime laboratories have the capability to scan web pages and folders on a computer system for hidden content.

COLLABORATION

This project is a collaborative effort between Iowa State University and the Iowa Division of Criminal Investigation (DCI). DCI serves as a consultant to the project and as a software tester and evaluator.

DISSEMINATION

Upon completion of the project, research findings will be presented at regional/national meetings and conferences, including the Digital Intelligence meeting, and if possible, the Internet Crimes Against Children (ICAC) conference. A manuscript on the research and its findings will also be prepared for submission to the *Journal of Digital Forensic Practice*, while a technical report on the project will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Davidson, J. and Jalan, J., “Feature Selection for Steganalysis using the Mahalanobi’s Distance.” Accepted for presentation and publication at the SPIE-International Society for Optics and Photonics, Media Forensics and Security XII Conference, January 2010, San Jose, CA.

IMPLEMENTATION

A beta version of the software package was installed on a computer at the DCI laboratory. Staff received instruction for use as well as a user’s manual. Feedback is used to make adjustments to the program. The final software program will

be demonstrated at regional/national workshops and conferences, and will be made available to interested parties through the MFRC.

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A Method for Lifting Bloody Impressions Using a Lifting Strip Containing Titanium Dioxide

FORENSIC TECHNOLOGY NEED

Bloody impressions are of great importance to the forensic science community as they are frequently encountered at crime scenes and on evidence submitted to the laboratory. Currently, there are a variety of techniques available for enhancing bloody fingerprints on some non-porous, semi-porous, and porous surfaces. However, depending on the surface porosity and background color, they require different enhancement processes. In addition, many of the processes require the use of toxic chemical reagents and need to be conducted in a laboratory setting. Since impression evidence in blood cannot always be removed from the crime scene for analysis in a laboratory setting, many potentially identifiable impressions can only be photographed and not enhanced.

TECHNOLOGY DESCRIPTION

In an earlier study, a lifting strip containing titanium dioxide was successful in lifting and enhancing bloody fingerprints from several non-porous and semi-porous surfaces of contrasting colors. The lifting strips worked best when activated with a surfactant. After drying, the strip could easily be removed from the surface, lifting the bloody fingerprint onto a contrasting white background for examination. To improve upon the methods used in the initial research, the primary objective of this study is to develop a better quality lifting strip and optimize the lifting process for use by the forensic science community.

METHODOLOGY

To achieve the objective, specific goals of the research are:

- Manufacture larger lifting strips conducive to lifting bloody hand prints, footprints, and footwear impressions
- Determine the effectiveness of the lifting strip on aged impressions
- Determine the effectiveness of the lifting strip on a larger variety of porous, semi-porous, and non-porous surfaces
- Conduct research trials lifting bloody handprints, footprints, and footwear impressions from a variety of different substrates
- Determine the saturation limits regarding the amount of blood lifted with each lifting strip
- Determine the effectiveness of the lifts when lifting pure proteinaceous blood samples
- Conduct trials of the lifted bloody impressions, utilizing various enhancement techniques
- Conduct presumptive DNA testing on the lifted impressions to determine if DNA is destroyed during the lifting process

ACCOMPLISHMENTS AND ONGOING WORK

Substrate materials were collected and sized for the deposition of bloody fingerprints, palm prints, footprints and footwear impressions. Some surfaces were treated with sealant, paint, and stain to provide a realistic view of what is encountered at actual crime scenes. Substrates were categorized (non-porous, semi-porous, and porous) and cut into small (1.5" x 2") and large (8" x 8") sample pieces. Additionally, 72 research boards were diagrammed

to secure substrate samples and lift impressions for the research trials.

An improved lifting strip was designed and manufactured for use in lifting bloody impressions and to address the needs of the forensic science community. The strips were made by bonding various titanium dioxide mixtures containing Kodak Photo-Flo, 5-Sulfosalicylic acid, Liqui-Nox, polymers, and water to a nylon membrane. The membrane was saturated in the titanium dioxide mixture to allow a uniform and thorough covering of the mixture onto the membrane, then dried to complete the bonding process. When dried, the lifting strips were sealed and used in all research trials.

Substrates	Aged Impressions - Lift Quality					
	1 Hr	1 Day	1 Wk	1 Mth	3 Mths	6 Mths
Nonporous: Aluminum (8µl blood)	***	***	***	***	N/A	N/A
Nonporous: Black Plastic (8µl blood)	***	***	***	***	N/A	N/A
Nonporous: Metal (8µl blood)	***	***	***	***	N/A	N/A
Semi-porous: Black Leather (12µl blood)	***	***	***	***	N/A	N/A
Semi-porous: Stained Wood (8µl blood)	***	***	**	*	N/A	N/A
Porous: Cotton (20µl blood)	***	***	***	***	N/A	N/A

Table 1. Results of lift quality

Aged bloody impressions were deposited on six substrates: three non-porous (aluminum, black plastic, metal), two semi-porous (black leather, wood), and one porous (cotton). Each of the substrates had ten bloody impressions deposited for aged trials: one hour, one day, one week, one month, three months, and six months. The lifting strips demonstrated their effectiveness in lifting bloody impressions from all six impression substrates through one week, with visible identifiable ridge detail through one month on all substrates except the stained wood.

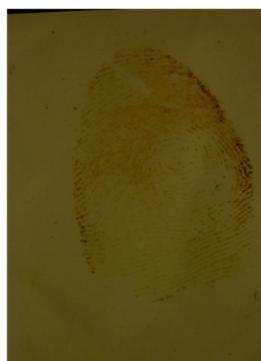
A bloody handprint was deposited on a glass substrate for a one-hour interval and then lifted with the lifting strip to provide an example of the strip's effectiveness on the larger lifts. The lifted bloody handprint displayed identifiable detail with exceptional clarity and contrast for analysis.



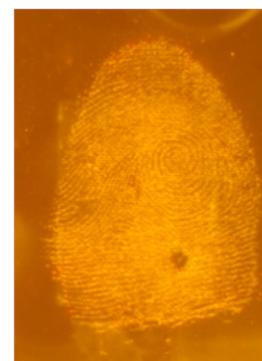
Figure 1. Semi-porous painted concrete



Figure 2. Porous denim



One Week, No Enhancement



One Week, Enhanced LCV

Figure 3. Aged impression one week – cotton

One sample from each substrate of the aged intervals was selected for enhancement with Leucocrystal

Violet (LCV). LCV was successfully used as an enhancement technique for bloody impressions that were lifted with the titanium dioxide lifting strip. The LCV darkened any of the visible bloody ridge detail by changing the light reddish-brown color of the ridge detail to a dark purple color. In viewing the LCV-enhanced bloody impression with an orange filter, the contrast and clarity of the ridge detail in the lifted impression greatly improved.

The PI is currently working on completing the substrate impressions for all 22 substrates. This includes large size lifts, determining the saturation limits regarding the amount of blood lifted with each lifting strip, and determining the effectiveness of the lifts when lifting pure proteinaceous blood samples. The PI is also conducting trials of the lifted bloody impressions utilizing various enhancement techniques, and conducting presumptive DNA testing on the lifted impressions to determine if DNA is destroyed during the lifting process.

TECHNOLOGY BENEFITS

Immovable objects from crime scenes cannot be brought back to the laboratory for analysis. Because of this, many potentially identifiable impressions may only be photographed and not enhanced, thereby complicating the latent print identification process. With the use of the new uniform lifting strip, these problems can be alleviated while still providing optimal quality impressions for analysis.

COLLABORATION

This is a collaborative effort among Madonna University, Northville Police Department; and the Michigan State Police (MSP) Northville Forensic Science Laboratory. The MSP Laboratory provides consultation and use of the photography equipment, while Madonna University provides laboratory space and financial oversight.

DISSEMINATION

The results of this study will be disseminated through presentations at forensic science conferences and at trade shows for the law enforcement community. A manuscript on the research findings will be submitted to the *Journal of Forensic Identification*. A technical report on the research will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

There are no publications or presentations to date.

IMPLEMENTATION

The MSP plans to field test the lifting strip with the intent to incorporate the method into the department's policies and procedures statewide.

The PI has had conversations with potential vendors for the lifting strip technology. If successful, the technology could be marketed to law enforcement and crime scene investigators nationwide.

CONTACTS

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Application of Face Recognition Technology to Microstamped Cartridge Cases

FORENSIC TECHNOLOGY NEED

Microstamping identification has been suggested as a way of providing an objective means to relate guns to fired ammunition. While the method shows promise, many questions remain, chief of which is the durability of the mark. To address this concern, a study is undertaken to determine if microstamped identifiers, imprinted onto firearm components for subsequent transfer to cartridge cases, can be recognized using a combination of imaging and software recognition methods.

TECHNOLOGY DESCRIPTION

Microstamping is a technique to etch individual serial numbers onto critical parts of a firearm. When the weapon is fired, the etchings are transferred to the cartridge case, thus allowing the cartridge cases to be related to the fired weapon.

The primary objectives of this project are to determine the ability of advanced imaging and recognition software; the durability of microstamped identifiers on three handguns; and whether a microstamped identifier can be recovered using metallurgical etching techniques.

METHODOLOGY

To achieve these objectives, the following steps are taken:

- Three different quality firearms are obtained, fired, cleaned, and polished at regular intervals
- The sequence of firing and cleaning is repeated until 1000 shots have been fired or the microstamped identifier is no longer visible
- Cartridge cases are collected after every 100th and 101st sequence of shots and imaged using a surface profilometer
- Characterization of the identifier is carried out using an optical profilometer
- Metallurgical etching methods are used to determine which identifier can be removed from the surface of the firing pin

ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that has not yet started work.

TECHNOLOGY BENEFITS

California recently signed into law a bill requiring microstamping that goes into effect January 1, 2010. Other states are also investigating use of the technology. The findings of this study may help states determine if microstamping is indeed a viable technology to link a firearm to a cartridge. The results may also aid in firearm investigations by providing a quantitative measure of the degree of match.

COLLABORATION

This project is a collaborative effort among Ames Lab, Iowa State University, Jim Kreiser (a retired toolmark examiner for the State of Illinois), and the Microstamping Technology Center, a division of Pivotal Development, LLC of Londonderry, NH.

Mr. Kreiser will assist in obtaining the required firearms and ammunition and oversee the test firings and cleaning of the weapons. The Microstamping Technology Center will mark the firing pins of the study weapons using the latest methods under development at Pivotal Development, LLC.

DISSEMINATION

Research findings will be disseminated through presentations at the Association of Firearm and Toolmark Examiners (AFTE) conferences and training seminars, as well as U.S. Department of Justice sponsored training and informational events. Presentations will also be made at conferences that have forensic sessions, like joint meetings of the Metallurgical Society/ASM International. A manuscript will be submitted for publication to the *Journal of Forensic Sciences*, the AFTE journal, and other relevant peer-reviewed journals. A final technical report on the project and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new project with no presentations or publications to date.

IMPLEMENTATION

The findings of this project can have significant impact on the implementation of microstamping as a technique for firearm identification. Should the technology be mandated by state or federal legislatures, the imaging/computer analysis system will only be needed in cases where the microstamp is not visible using a low power microscope or where microstamped identifiers have been removed. It is anticipated that wide-scale implementation will be less costly than the current National Integrated Ballistics Information Network (NIBIN) system.

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Discrimination of Dyed Cotton Fibers Based on UV-visible Microspectrophotometry and Multivariate Statistical Analysis

FORENSIC TECHNOLOGY NEED

UV-visible microspectrophotometry (UV-MSP) is a popular technique used by trace evidence examiners for characterizing fiber color. While fast and generally considered to be highly discriminating, sample association with UV-MSP can be problematic due to sample heterogeneity and a lack of quantitative criteria for comparing spectra. To establish the validity of UV-MSP for fiber examinations, a systematic study is needed to develop a quantitative approach to the comparison of MSP data. This project evaluates the use of Multivariate Statistical Analysis to discriminate dyed cotton fibers.

TECHNOLOGY DESCRIPTION

UV-visible microspectrophotometers are instruments designed to measure the UV-visible spectra of microscopic samples. With specialized software, they can be used to measure thin film thickness, colorimetry, and more. Preliminary results demonstrate that replicate spectra from fibers treated with different dyes form distinct clusters with spectra showing systematic differences. Statistical analysis further reveals that classes of dyes can be identified, leading to possible development of a dye classification scheme. This project builds upon the results of the preliminary study.

METHODOLOGY

The objectives of this project are to acquire a collection of dyed cotton fibers, acquire spectra from all samples using UV-MSP, and perform multivariate statistical analysis on the resultant spectra at two different laboratories to test the null hypothesis that the mean of a group of spectra from one laboratory is significantly different from the

mean of a group of spectra from another laboratory. An additional test of consistency among data sets is employed by comparing the classification accuracy upon merging the two data sets to the classification performance of the separate tests.

Two popular data treatments are then evaluated for these collections of spectra. The first is a calculation of first derivatives and the second is a transformation of the spectra into chromaticity coordinates. In each case, the multivariate calculations are repeated on the modified spectra and any differences in classification are noted to determine the extent to which spectra can be differentiated and shared between laboratories.

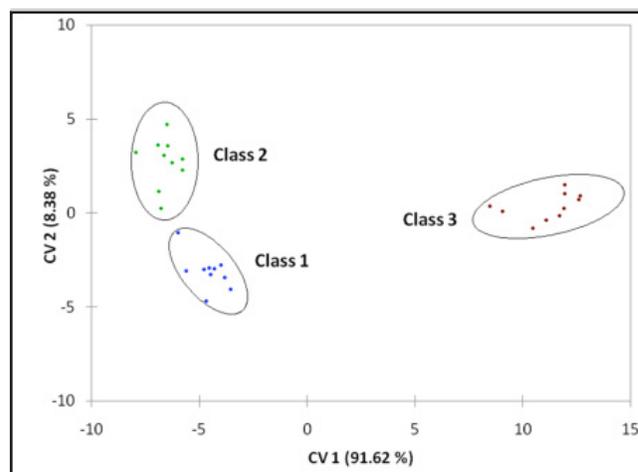


Figure 1. Discriminant analysis representation of data (Class 1 = Direct Red, Class 2 = Reactive Red 120, Class 3 = Reactive Red 123)

ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that has not yet started work.

TECHNOLOGY BENEFITS

Trace evidence examiners generally do not have any quantitative basis for determining the

probative value of an evidence type in question, which analytical method is the most discriminating for that evidence type, the effect of intra-sample variance on drawing their conclusion, or an objective criterion for comparing two samples. By applying multivariate statistical approaches to UV-MSP data gathered from dyed cotton fibers, the understanding of trace evidence and the evaluation of the match of questioned and known samples will be greatly improved.

COLLABORATION

This project is a collaborative effort among Indiana-University-Purdue-University-Indianapolis (IUPUI), the Indiana State Police (ISP) Forensic Science Laboratory, and the University of South Carolina (USC). The ISP will participate in the analysis of cotton fibers using their CRAIG QDI 1000 instrument and provide guidance to the project. Dr. Stephen Morgan (USC) will provide software specifically written for multivariate analysis of fiber spectra.

DISSEMINATION

The results of this research project will be disseminated at various forensic science conferences such as Midwestern Association of Forensic Scientists and the American Academy of Forensic Science. Research findings may also be published in peer-reviewed journals such as the *Journal of Forensic Sciences* and *Forensic Science International*. A final technical report will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new research project with no publications or presentations to date.

IMPLEMENTATION

Upon completion of the research, results may warrant the development of a set of guidelines submitted to the ISP Lab and the Scientific Working Group on Materials Analysis for the benefit of fiber examiners.

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Informing the Judgments of Fingerprint Analysts Using Quality Metric and Statistical Assessment Tools

FORENSIC TECHNOLOGY NEED

The National Academy of Sciences (NAS), in its recent report *Strengthening Forensic Science in the United States: A Path Forward*, states that the latent print community has eschewed numerical scores and corresponding thresholds because those developed to date have been based on minutiae.

To address these concerns, a study is undertaken to determine if a “Quality” tool (to measure the clarity of the friction ridge) and a “Statistical Diagnostic” tool (to provide statistics that measure the strength of the evidence) might benefit fingerprint examiners during their decision making.

TECHNOLOGY DESCRIPTION

Specific objectives of the project are to:

- Determine how information regarding the clarity of friction ridge features (as provided in various formats to the participants) will inform the judgments of fingerprint analysts
- Determine how information regarding the strength of the corresponding friction ridge features (as provided in various formats to the participants) will inform the judgments of fingerprint analysts
- Determine how information regarding the strength of the corresponding features when provided by *other* fingerprint experts (“Expert Consultation”) will inform the judgments of the participating analysts

METHODOLOGY

To achieve these objectives, the impact of the

“Quality” and “Statistical Diagnostic” tools and “Expert Consultation” on fingerprint examiner decision making is assessed. Six experimental groups will be used, applying combinations of the three tools.

Variables	No LR tool	Expert consultation	Diagnostic LR tool
No quality tool	Group 1 No quality tool No LR tool	Group 2 No quality tool Expert consultation	Group 3 No quality tool LR tool
Quality tool	Group 4 Quality tool No LR tool	Group 5 Quality tool Expert consultation	Group 6 Quality tool LR tool

Table 1. 2x3 testing matrix to accomplish the stated objectives

The measured variables for the effect on examiner performance are the accuracy and reproducibility of the conclusions against the ground truth (including the impact on error rates) and the analyst variation during feature selection.

The hypothesis is tested that experts will benefit from the implementation of tools that objectively assess clarity of friction ridge features and provide statistics regarding the strength of a match.

ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that has not yet started work.

TECHNOLOGY BENEFITS

This research will provide guidance on how best to integrate technology while maximizing analyst expertise and expert interpretation. In doing so, the research will ultimately address the concerns of the NAS and provide an essential link between the theoretical/ research models and actual examiner implementation during casework.

COLLABORATION

The project is a collaboration among the Minnesota Bureau of Criminal Apprehension (BCA), the University of Lausanne Switzerland (UNIL), and the Arizona Department of Public Safety Crime Laboratory.

Glenn Langenburg (Principal Investigator) is currently a Certified Latent Print Examiner at the BCA. He is also a Ph.D. candidate in forensic science at UNIL. This project represents a portion of his work towards completion of the Ph.D. program.

DISSEMINATION

The results of this project will be presented at the International Association for Identification (IAI) Annual Educational conference. If warranted, research findings will be submitted to the *Journal of Forensic Sciences* for publication. Research results will also be presented at UNIL as part of a thesis defense, with a final technical report posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new research project with no publications or presentations to date.

IMPLEMENTATION

Since the forensic community at large may need education and training on how to express statistical evidence when reporting or testifying, the results of this research may be used for training examiners on how to express statistical evidence in reports and testimonies.

Depending on the results of the experiment, recommendations will be made to the latent print community via the IAI Standardization II Committee and via SWGFAST (Scientific Working Group on Friction Ridge Analysis, Study, and Technology). These recommendations may

include implementation of “Quality” metric and “Statistical” measurement tools for assessing case work.

CONTACTS

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Physical Matching in Trace Evidence: A Validation Study Using Automobile Parts

FORENSIC TECHNOLOGY NEED

Physical matching is considered to be a process which is intuitively obvious. In trace evidence, physical matches are used to demonstrate that the fracture surfaces are generated from the same part. In spite of the wide use and reliance of forensic examiners on the physical match, there is a lack of validation studies which document the reliability of physical matches.

TECHNOLOGY DESCRIPTION

A common scenario in Trace Evidence is a hit-and-run accident. Pieces of vehicular debris including glass, paint, plastic, wood, tape, and fabric are often left at the scene by a fleeing automobile. They can be collected for physical matching to a suspect vehicle.

A physical match is a compelling piece of physical evidence that can be used to place the vehicle at the scene of the accident. The primary objective of this study is to validate the physical matching process of questioned automotive parts to a known vehicle.

To test the hypothesis that relatively inexperienced persons can reliably determine the realignment of fragments, a study is undertaken to validate the physical matching process and to assess error rates associated with this type of examination.

METHODOLOGY

To achieve the objective, intact automobile parts from the front ends of vehicles commonly operated in the United States are obtained from salvage yards or from auto part outlet stores. The parts, in particular turn-signal housings, headlight assemblies, and side-mirror housings are damaged

with a piece of wood to simulate an automobile accident.

The broken fragments of the assemblies are collected to simulate debris recovered at the scene of the accident. A group of students is used to demonstrate and validate the physical matching of simulated crime scene fragments and to calculate error rates.

Students are chosen because they are technically laypersons and representative of newly-hired analysts entering a training program in physical matching.

ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that has not yet started work.

TECHNOLOGY BENEFITS

Physical and fracture matching have long been accepted in courts of law and have been considered intuitively obvious processes which even a layperson can understand and perform. In the process of defending a physical match on the witness stand, the analyst appeals to the layperson's concepts of jigsaw puzzles and lock-and-key fits.

Relatively little has been done in the way of formal scientific processes to train or define physical matches relative to other fields of analysis. This study tests the hypothesis that a given physical match is indeed an intuitive process accessible to a layperson.

COLLABORATION

This project is a collaborative effort between the Trace Unit of the Wisconsin State Crime Laboratory-Madison and the University of

Wisconsin-Platteville (UWP) Department of Chemistry and Engineering Physics. UWP will recruit and coordinate student employees and conduct statistical analyses of the research data.

DISSEMINATION

The results of this study will be presented at annual meetings of the Midwestern Association of Forensic Scientists and the American Academy of Forensic Sciences. Publication in relevant peer-reviewed journals will also be pursued. Upon completion of the project, a technical report on the study and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

This is a new project with no presentation or publications to date.

IMPLEMENTATION

It is anticipated that publication of the project findings in a peer-reviewed journal will provide a citation basis for laboratory findings used in court cases.

CONTACTS

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Three-dimensional Quantification of Characteristics of the Human Dentition

FORENSIC TECHNOLOGY NEED

Daubert vs. Merrell Dow Pharmaceuticals established several factors for the admissibility of scientific evidence. One factor not available to forensic odontologists is the ability to scientifically quantify the occurrence of specific dental characteristics in the population. Another is the error rate in the analysis of bite marks. Without these abilities, odontologist conclusions lack a scientific basis for probability expressions and are limited to subjective opinions.

TECHNOLOGY DESCRIPTION

The project is a continuation of a previously-funded study quantifying six dental characteristics in two dimensions. This study targets the quantification of the same six dental characteristics in three dimensions. The objective of the project is to refine and validate the data derived in the previous study using the third dimension to obtain, in a more discriminatory fashion, the width of each individual tooth.

METHODOLOGY

The development of an automated software application package in the previous study (i.e., Tom's Toolbox) to measure dental characteristics, along with the availability of computerized tomography, has made it possible to conduct forensic analyses of pattern evidence derived from a three-dimensional source.

The null hypothesis for this study is that the pattern measurement of the widths of the incisor teeth in three dimensions (3D) will not provide more accurate data than the two dimensional (2D) method on the widths of the incisor teeth that are not on the same occlusal plane.

To test this hypothesis, the 3D study compares the data obtained from the 2D measurements of imprints derived from dental models with the measurements taken from the same dental models using a Cone Beam Computed Tomography (CBCT). The widths of the incisor teeth on the 3D point cloud images are then measured at three levels on the Z axis.

ACCOMPLISHMENTS AND ONGOING WORK

Using Predictive Analytics (formerly SPSS) software, the sample size for this study was determined to be 50 upper and lower dental models. The requisite models were collected, 2D imprints registered, and scanned on a professional flatbed scanner following the guidelines of the Scientific Working Group on Imaging Technology (SWGIT).

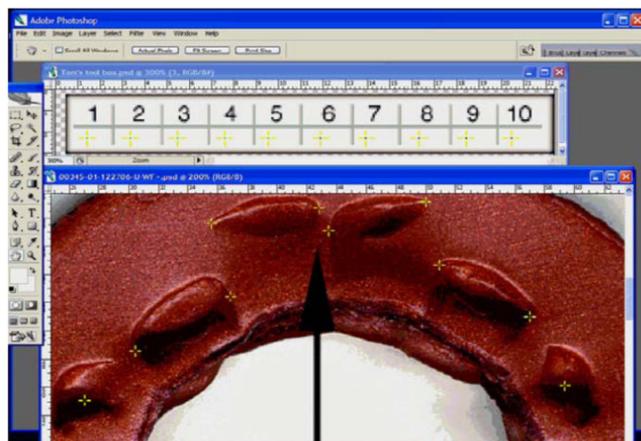


Figure 1. Application of Tom's Toolbox automated software

Original scans were archived on the university server and working files for each investigator were created from duplicated images of the samples. Utilizing the Tom's Toolbox automatic software application developed at Marguerite University, 100 of the 2D exemplars derived from the 50 sets of

dental models were measured by the two principal investigators.

A Soredex Scanora Cone Beam 3D dental imaging system was used to obtain 3D exemplars from the same 50 models. To achieve the precise orientation of each of the models for the CBCT scan, an adjustable platform was used that was provided by the manufacturer. Additionally, a laser beam level was used to establish proper orientation on the X, Y, and Z axes.

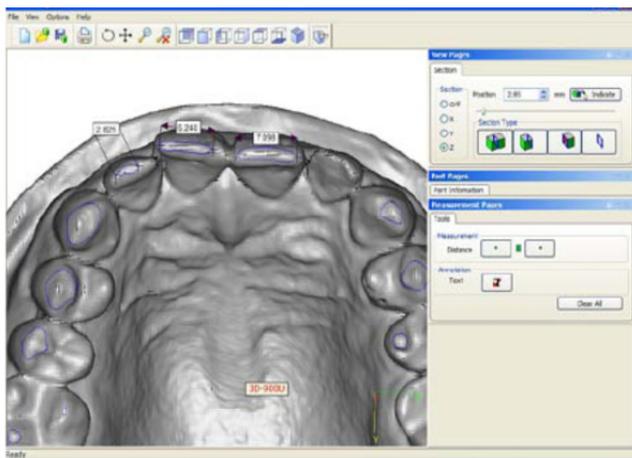


Figure 2. Example of measurement of incisor width at 0.5 mm on the Z plane

Three-dimensional images of the 50 models were archived in Digital Imaging and Communications in Medicine (DICOM) format, while duplicate images for measurement of the incisor width were created in STL format. This was accomplished utilizing the “Create Model: DICOM to Standard Template for Stereolithography (STL)” software application from Anatomage, Inc. Image analysis in the MiniMagics application required that the DICOM file format be converted to an STL format.

Quality control of the accuracy and reliability of the 3D scans was maintained by repeating 10 scans of a model to which a 5 mm radiographic ball was affixed. Using the measurement tool in the MiniMagics software, the “equator” of the ball was stabled and measured on each of the 10

STL images. Comparison of the 10 independent measurements showed the accuracy of the scans.

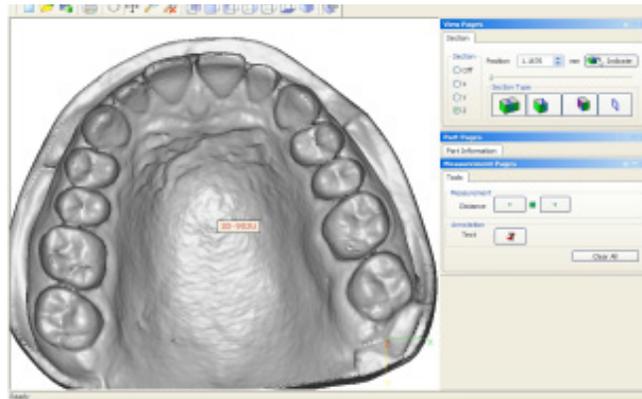


Figure 3. STL model imported into MiniMagics

Ongoing research focuses on statistical analysis of the data obtained. A comparison of individual 2D and 3D tooth width measurements at the 1.5 mm level of the Z plane will be conducted, along with a comparison of 2D tooth width measurements at 1.5 mm with 3D tooth measurements at the 0.5 mm, 1.0 mm, and 2.0 mm levels.

The quantification of 3D tooth widths will be calculated for each investigator and inter-and intra-observer variability established. This is particularly important in determining error rates since there is a greater chance of observer disagreement in 2D measurements.

TECHNOLOGY BENEFITS

The ability to scientifically express the probable linkage between a human bitemark and a suspect establishes credibility and admissibility of bitemark analysis. This study provides crime laboratory imaging staff with the ability to accurately quantify measurements and angles of rotation of teeth in patterned evidence, thereby also providing a scientific basis for opinion testimony on the probability of a match.

COLLABORATION

The project is a collaborative effort among the University of Marquette and the Wisconsin State Crime Laboratories in Milwaukee (WSCL-Mi) and Madison (WSCL-Ma). The Wisconsin State Crime Laboratories provide two imaging specialists to serve as consultants. They help in setting up the protocol, calibrating, and testing the imaging hardware. This ensures that the methodology conforms to the guidelines of SWGIT and that reliable data are documented.

DISSEMINATION

The findings of this study are disseminated through presentations at national and international meetings and through publication in the *Journal of Forensic Identification*. Upon completion of the project, a final technical report on the study and its findings will be posted on the MFRC website.

PUBLICATIONS AND PRESENTATIONS

- Johnson, L.T., Radmer, T., Wirtz, T., Yang, M., “Can Tooth Displacement Be Quantified?” Presented at the International Association for Identification, 49th Educational Conference, August 2009, Tampa, FL.
- Johnson, L.T., Radmer, T., Wirtz, T., Yang, M., “3D Pattern Analysis: Methodology.” Presented at the International Association for Identification, 49th Educational Conference, August 2009, Tampa, FL.
- Johnson, L.T., “Can Tooth Displacement Be Quantified?” Accepted for publication in the *Journal of Forensic Identification*, January/February 2010.

IMPLEMENTATION

The study is ongoing and no opportunities for implementation have surfaced to date.

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