Introduction
The need to handle ever increasing sample numbers with the same level of resources poses many challenges for forensic laboratories. Data analysis and review remains a very time consuming activity and drives forensic laboratories to seek automated solutions that enable them to reduce significantly the amount of analyst time required to interpret large volumes of data. Expert systems can be an efficient means of minimizing the time needed for analysis of routine forensic databasing samples but are not always able to make the final analysis decisions for casework samples due to the interpretation complexities involved. Forensic laboratories require a complete software solution that can act as an Expert System for routine samples in their workflow and an Expert Assistant to aid in manual review of data and mixture interpretation. By automating as much of the analysis workflow as possible, for all types of forensic samples, the analyst is empowered to make key interpretation decisions more quickly and confidently.

GeneMapper® ID-X Software
Expert System and Expert Assistant Software for Forensic DNA Analysis

- Powerful, easy-to-use data analysis tool designed to increase lab productivity
- Comprehensive Expert System capability for databasing laboratories delivered by automated data assessment functionality and efficient manual review tools
- Complete Expert Assistant solution for casework laboratories combining an efficient suite of manual review features with an integrated Mixture Analysis tool
- Quality control functionality allows rapid allele match comparisons and concordance searches within a data set
- Extensive security, auditing and e-signature capabilities help to protect data integrity and provide additional control of technical records
- Multi-User database configuration facilitates information exchange
**FORENSIC DATA ANALYSIS WORKFLOW**

Figure 1. The workflow above represents how GeneMapper® ID-X Software processes samples as either an Expert System or an Expert Assistant.

GeneMapper® ID-X Software is a powerful data analysis solution designed specifically to fulfill the requirements of Expert System and Expert Assistant software. A combination of sophisticated automated data assessment processes and efficient manual review tools significantly reduces the amount of analysis time required for all types of forensic samples. Unparalleled Expert System features quickly and easily identify samples which meet all analysis criteria and highlight those that do not. The automated review performed by the software highlights those samples meeting all analysis criteria and provides detailed information on the remainder to facilitate the manual review performed by the analyst.

**Comprehensive Expert System Functionality**

Despite its ability to automate and streamline the analysis of single source samples, expert systems are often unable to make the final analysis decision for most forensic casework samples, especially those containing mixtures. It is possible, however, to harness the automated, rule-based, subject-specific knowledge on which an expert system is based to enable the software to act as an Expert Assistant to the forensic analyst, simplifying much of the analysis process and empowering the analyst to make key interpretation decisions consistently. Of all the stages involved in the analysis of casework evidence, interpretation of mixed samples is one of the most difficult and time-consuming. Despite this, many of the steps in this process can be automated based on a series of rules, which, once optimized and validated, can guide the analyst to make a more informed decision based on all of the available data. With the GeneMapper® ID-X Software, forensic analysts can manage their forensic casework data review more quickly and with more confidence. The Forensic Data Analysis Workflow shown in Figure 1 represents how GeneMapper® ID-X Software processes samples as either an Expert System or an Expert Assistant.

**Figure 2.** The analysis summary provides a quick snapshot of the results of data analysis. The summary is interactive and links results to a specific category of samples.
Automated Data Assessment
GeneMapper® ID-X® Software has been developed with the human identification workflow in mind so that the novel features introduced to improve the data analysis process link together to provide optimal interaction between the analyst and the data.

Analysis Requirements Check
To help ensure all analysis requirements are met before analysis starts, a series of analysis requirements checks are performed.

Allelic Ladder Quality Assessment
GeneMapper® ID-X® Software uses a rule-based system which quickly separates those ladders suitable for genotyping from those of poor quality which may adversely affect the allele designation process.

Analysis Summary
This feature provides a quick snapshot of the results of data analysis. Separate sections of the summary indicate the analysis outcome for allelic ladders, controls (positive, negative and custom controls) and unknown samples.

The summary is interactive and links results to a specific category of samples [Figure 2].

Comprehensive Quality Value System
GeneMapper® ID-X® Software uses a quality value system to assess data quality at different points in the workflow at both the sample and marker level. Different aspects of the data are evaluated at each level, the assessment being displayed as a colored quality flag.

Manual Review Tools
Data analysis efficiencies offered by the automated data review processes have been further enhanced through the introduction of a new suite of manual review tools.

These developments focus around the plot window providing quick and easy access to all aspects of the data, thus simplifying the data review process [Figure 3].

Manual Review Tools
The software is capable of handling different types of labels. In addition to traditional allele labels, artifact labels are applied automatically to data spikes (identified through an intelligent rule set) and can be defined and applied manually by the user to other data anomalies.

Quality Value Details Window
The plot window offers the option to display marker specific quality value details. This includes thresholds for each of the marker-level quality flags defined in the analysis method along with the actual values obtained.

Color-Coded Marker Header Bars
Marker header bars, color-coded to match the genotype quality flag, allow the user to quickly identify the markers where anomalies are present and decide whether to edit, accept or reject the results [Figure 3].

Electronic Peer Review
Genotypes can be manually accepted at both the marker and sample level, providing evidence that the sample was manually inspected by the analyst and, together with a detailed label edit table display, providing an efficient mechanism for electronic/peer review of the data [Figure 4].

Quality Control & Data Comparison
GeneMapper® ID-X® Software offers the ability to use multiple custom control samples in addition to the kit positive control contained in each AmpFSTR® kit. The profile comparison tool allows the user to: (1) check the concordance of all designated controls; (2) determine if negative controls and reagent blanks affected by contamination contain similar profiles to samples amplified as part of the same batch or to laboratory personnel; and (3) perform comparisons between all samples contained within a project.

Mixture Analysis Tool
Once samples have been analyzed within a GeneMapper® ID-X® project, they can be imported directly into the Mixture Analysis tool where samples are rapidly separated based on the minimum number of contributors within the sample. Individual contributors to 2-person mixtures can then be extracted based on rules assessing mixture proportion and peak height ratios for all possible genotype combinations. A ranked display of possible genotype combinations is then created which minimizes the number of combinations an analyst must evaluate. The list of possible combinations can be further reduced if a known genotype is used during the extraction process. Based on the number of contributors identified within the sample, the software performs the appropriate set of statistical calculations including Random Match Probability (RMP), Combined Probability of Inclusion/Exclusion (CPI/CPE) and Likelihood Ratio (LR). All calculations utilize allele frequencies contained in population databases contained in the
The Client Installation contains the GeneMapper® ID-X Software only, without the database. Client users are able to access projects and settings stored in the centralized database associated with the Full Installation from a local workstation. This reduces significantly the need for export and import of software objects and helps ensure that all users access a single source of analysis settings. 

Optimization and Validation
Automated data review processes such as those used by the GeneMapper® ID-X Software require optimization and validation in order to determine the appropriate settings for the thresholds governing how data is interpreted. Thresholds may differ depending upon the instrument and chemistry being used or by the types of samples being processed. Therefore, it is important that for each combination, the software is tested using a variety of single source and casework samples that challenge each of the different quality flags. Default settings are suggested within the software but these should be adjusted based on the outcome of each laboratory’s own internal evaluation of the GeneMapper® ID-X Software. Optimizing any software for use as an expert system will require an additional investment on the part of the laboratory. To relieve some of the training and validation burden associated with implementation, the GeneMapper® ID-X software employs a similar user interface and identical peak detection and sizing algorithms to the GeneMapper® ID v3.2.1 Software. An extensive system verification and simulated expert system optimization have been performed at Applied Biosystems and a summary of the verification studies performed will be available to users as a reference and to provide guidance to those looking to implement the software.

Flexible Data Output Formats
Flexibility of table output format is essential to help feed the data into downstream applications such as LIMS. The Report Manager allows the user to create tables in horizontal or vertical format, control the exact column order and change the name of column headers if required.

Chain of Custody for Electronic Data
To address evolving requirements for the management and auditing of electronic data, the GeneMapper® ID-X Software offers comprehensive auditing, security, and e-signature capability. This functionality can assist labs to be compliant with ISO 17025 capability. This functionality can assist labs to be compliant with ISO 17025.

Multi User Database GeneMapper® ID-X is available in two installation configurations, Full Installation and Client Installations. A Full Installation consists of the GeneMapper® ID-X Software and database.