Adaption of the Chumbley Score to matching of bullet striation marks

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1 Introduction

Compairing pairs of toolmarks with the intention of matching it to a tool has been studied many times in the past. Extensive examples in literature for tools and toolmark research ranging from screwdrivers to groove pliers to slip-joint pliers can be found in the work of Faden et al. (2007), Bachrach et al. (2010), Miller (1998), Grieve et al. (2014) and many more. In comparison to this, same source matching of bullets to firearms has not been examined as prominently as that of toolmarks, with even less information available on validity of methods and error rates associated with firearms examination. The National Academy of Sciences in its report in 2009 (National Research Council 2009) discussed the need for determining error rates in methods proposed for firearms examination. In the context of same source matching and error rates determination, as seen in the case of most forensic applications, the first step involves identification of unique features that are characteristic of the object at hand. For the case of bullets and firearms, striation marks on the surface of the bullet are considered to be such markings that can be used in methods for same source matching. These marks are often a product of rifling and impurities and defects due to manufacturing in the barrel of the gun, which leads to engravings on the bullet surface (AFTE Criteria for Identification Committee 1992). In current practice, firearm examiners invariably make visual comparisons of bullet striae and use visual assesment tools to dignify bullets as being matches and non-matches. One way of accomplishing anykind of comparison between bullets is to do a comparison between surface marking of two or more bullet lands. Bullet Lands are considered to be areas between grooves made by the rifling action of the barrel. These marking are considered to be unique. The land engraved markings or sometimes termed as Bullet profiles (Hare et al. 2016) are striation marks made on Bullet lands and often used for these land to land comparisons. Bullet Signatures is another word used in literature as seen in the work of Chu et al. (2013) and Hare et al. (2016). In our context bullet signatures refer to a processed version of the raw land engraved markings or profiles. The generation of bullet signatures involves first extraction of a bullet profile by taking the cross-sectional of the surface at a given height and then using loess fits to model the structure. The residuals of this fit are called signatures, which are considered to be noise free and a good reflection of the class charecteristics and unique features of a bullet. A more detailed version of the extraction technique of signatures is discussed by Hare et al. (2016), where comprehensive details about the height at which profile is to be selected, removing curvature, smoothing, identifying groove locations are explained.

In the study conducted by Hare et al. (2016) a machine learning based algorithm was developed for same source matching of bullets and error rates were discussed using the database from the Hamby Study (Hamby et al. 2009). In this paper, we first try to adapt a deterministic algorithm and method developed for toolmarks by Chumbley et al. (2010) and improved by Hadler & Morris (2017), to bullets. Then we consequently discuss about the efforts in doing so along with the associated error rates. The data used in this paper also belongs to the Hamby Study (Hamby et al. 2009). This gives us a common platform for comparing the performance of the chumbley method on bullets with an already existing method proposed by Hare et al. (2016) for bullets. The proposed algorithm and method of Chumbley et al. (2010), in their paper, compares two toolmarks with the intention of determining if it comes from the same source (same tool). The method also provides a means to determine error rates and claims to reduce subject bias. As mentioned earlier, subject bias and error rate determination have been a long standing issue in firearm examination (National Research Council 2009). This remains one of the motivations to explore the adaptibility of the Chumbley score methodology to bullets. Chumbley et al. (2010) used an empirical based setup to validate their proposed algorithm and quantitative method which calculates a U-statisic for the purpose of classification of toolmarks as matching or non-matching. The data for their study was obtained from 50 sequentially manufactured screwdriver tips, and preselected comparison window sizes were given as inputs to the algorithm. The algorithm then compares the two toolmarks and comes up with a U-statistic and an associated p-value to designate them as matches or non-matches. The performance for every 100 comparisons, of the algorithm proposed by Chumbley et al. (2010) and the improvement proposed by Hadler & Morris (2017) are listed in the table below.

Table 1: Chumbley et al. 2010

Classification	Match	Non-Match
Match	41	9
Non-Match	2	48

Table 2: Hadler et. al. (2017)

Classification	Match	Non-Match
Match	47	3
Non-Match	0	50

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