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Role of automation in the examination of handwritten items

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ABSTRACT

Several automation tools have been developed over the years for forensic document examination (FDE) of handwritten items. Integrating the developed tools into a unified framework is considered and the essential role of the human in the process is discussed. The task framework is developed by considering the approach of computational thinking whose components are abstraction, algorithms, mathematical models and ability to scale. Beginning with the human FDE procedure expressed in algorithmic form, mathematical and software implementations of individual steps of the algorithm are described. Advantages of the framework are discussed, including efficiency (ability to scale to tasks with many handwritten items), reproducibility and validation/improvement of existing manual procedures. It is indicated that as with other expert systems, such as for medical diagnosis, current automation tools are useful only as part of a larger manually intensive procedure. This viewpoint is illustrated with a well-known FDE case, concerning the Lindbergh kidnapping with a new hypothesis – in this case, there are multiple questioned documents, possibility of multiple writers of the same document, determining whether the writing is disguised, known writing is formal while questioned writing is informal, etc. Observations are made for future developments, where human examiners provide handwriting characteristics while computational methods provide the necessary statistical analysis.

1. Introduction

The examination of handwritten items is the most common task in forensic document examination (FDE). The examiner has to deal with various aspects of documents, e.g., paper, ink, handwriting characteristics, visual layout, etc., with writership being the central issue. Procedures for handwriting FDE have been described over the course of a century [1–5]. The focus of the present paper is on the role of artificial intelligence (AI) and software tools in the task of examining handwritten items. The ultimate AI goal is to make the current human procedure more efficient, easily replicated and validated. The approach can be regarded as *computational thinking* applied to FDE. We also consider limitations to the AI approach based on currently available methods.

1.1. Computational thinking

Computational thinking is a way to solve problems, design systems, and understand human behavior [6]. Drawing on concepts of computer science, the solutions are represented in such a way that they can be processed by an information processing agent, e.g., software. First put forward by the AI pioneer Seymour Papert, computational thinking may be essential to flourish in today's world. By systematizing human procedures they can be better understood, validated and improved.

The main elements of computational thinking are abstraction, algorithmic thinking, mathematics and scaling. In the process of abstraction the main elements are retained while unnecessary details are eliminated. More specifically, in computer science, by using abstraction, the programmer reduces and factors out details so that he/she can focus on a few concepts at a time. Abstraction is useful to understand and solve problems more effectively.

An algorithm is an effective method expressed as a finite list of well-defined instructions for calculating a function. The use of mathematics is to precisely perform the calculations. Algorithms and mathematics allow the development of an efficient, fair and secure solution. The type of mathematics used most often in AI is probability theory – as a tool to represent uncertainty.

Scalability in computer science refers to the capability to handle a growing amount of work in a capable manner. It is necessary to understand scalability for the sake of efficiency as well as for economic and social reasons.

Computational thinking is useful in domains where human judgement is involved. In order to develop a useful AI system for a given domain a considerable amount of *reverse-* or *knowledge-engineering* is necessary.

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1.2. Application to jurisprudence

Before fully endorsing the computational approach, a retrospective of such approaches to jurisprudence provides a cautionary tale. Systematizing legal procedures has long been a dream. Logical rules to automate the verdict go back to the days of the Napoleonic code where the goal was to minimize discretion and maximize predictability of outcome. With its stress on clearly written and accessible law, the Napoleonic code is one of the most influential books ever written. It influenced the replacement of a patchwork of feudal laws throughout Europe after the Napoleonic wars. Yet, it floundered in practice because of vagueness of words and the infinite variations found in the real world.

Another similar effort, undertaken nearly two centuries later, is expert systems that attempt to fully automate a human process, and in particular as replacements of the judiciary [7]. Such AI systems have met with similar failure both in terms of success and uptake, e.g., one disadvantage of fully automated systems is their lack of explanatory power in justifying the decisions made. These approaches to full automation have been referred to as *mind-narrowing* by the AI researcher Alan Bundy [8].

In contrast, better inroads have been made by legal reasoning systems that merely assist in legal decisions, e.g., construct hypotheses for evidence in a crime scene and remind detectives of hypotheses they might have otherwise missed. These systems may be referred to as *mind-expanding*. They avoid the pitfalls of mind-narrowing systems.

1.3. Application to forensic science

Ever since the landmark ruling *Daubert v. Merrell Dow Pharmaceuticals* [9] there has been a need to develop a scientific basis for each of the forensic sciences. This has led to the so-called Daubert hearings where the burden of the side presenting forensic evidence is to demonstrate that the procedure has been validated, undergone peer review, error rates established, can be replicated, and is generally accepted. The need for validation is vital to the forensic sciences as it proceeds towards a stronger scientific basis [10]. Computational thinking offers to forensic science a means of reproducibility and validation. In economic terms, the processing of large amounts of evidence in a short period of time using few resources is essential. Applying computational thinking to forensic procedures is computational forensics [11].

Within the forensic sciences, impression evidence is a classical area with several hundred years of history. Impression evidence includes handwriting, latent prints, footwear marks and tire treads. There are numerous legal rulings regarding the admissibility of handwriting evidence in the courts; several dozen pertaining to the U. S. courts are referenced in [12].

Analysis of handwriting for determining *writership* continues to be primarily based on human judgement. The success of the easier task of machine *recognition* of handwriting [13,14] provides optimism that the same can be done with FDE. A computational procedure would make such a Daubert demonstration easier.

1.4. Handwriting software tools

Several computational methods for handwriting examination have been developed over the last two decades by the pattern analysis and machine intelligence community [14,15]. Some are in the form of generally available software systems and others are purely research endeavors. Specific systems include FISH [16], CEDAR-FOX [17,18], and FLASH-ID [19]. Such tools, which have the capability of extracting handwriting features for the purpose of side-by-side comparison, have been used to establish scientific foundations such as the individuality of handwriting [17,19] and quantifying the strength of evidence as a likelihood ratio [20]. Yet, handwriting examination practice continues to be a largely manual intensive effort based on FDE training. The situation is not dissimilar to expert systems where automation is only a part of the process, e.g., medical diagnosis, where the stakes are high.

1.5. Organization of rest of paper

We first describe the standard procedure for the examination of handwritten items (Section 2). Then we represent the procedure as an algorithm in Section 3, together with descriptions of methods to algorithmically implement some of the steps. To illustrate the computational approach, a concrete FDE example involving handwriting is considered in Section 4 – it relates to the well-known Lindbergh kidnapping case together with a new hypothesis. The case provides a diverse range of problems such as extended writing, disguise, formal writing, extraction of image regions, adequacy of writing, and formulating a statement of opinion. It also shows where human FDE input is needed so that a more effective human–machine system can be designed as discussed in Section 5. Finally in Section 6 we summarize the current state of automation and discuss future prospects.

2. Human FDE procedure

Methods to examine handwritten items have been described in numerous books, guidelines and standards. For instance, the requirements, before handwriting comparison can be undertaken, are summarized as *CAT*: (i) known exemplars are *comparable* to the disputed text, (ii) they are *adequate* in amount and (iii) they are *timely* or contemporaneous [4].

The ASTM document *Standard Guide for Examination of Handwritten Items* [21] lists the steps that must be followed. Hereafter referred to as the *standard procedure*, it represents the knowledge engineering necessary for an expert system.

2.1. Questioned document (QD) terminology

While human oriented FDE procedures have a long history, there have been many computer algorithms and software has been developed over the last few years for various tasks in FDE. The vocabulary of pattern recognition is quite different from that of FDE since they have been developed almost independently. Thus the two distinct terminologies need to be integrated for a unified solution. We first describe some of the vocabulary of FDE, as described in [21], since it is necessary to describe the procedure.

absent character: present in one body of writing and not the other
character: language symbol: letter, numeral, punctuation
characteristic: a feature, quality, attribute or property
class characteristics: properties common to a group
comparable: same types, also contemporaneous, instruments
distorted: unnatural: disguise, simulation, involuntary
handwritten item; cursive, hand-print or signatures
individualizing characteristics: unique to individual
item: object or material on which observations are made
known (K): of established origin in matter investigated.
natural writing: without attempt to control/alter execution
questioned (Q): source of question, e.g., common with K
range of variation: deviations within a writer's repetitions
significant difference: individualizing charac. outside range
significant similarity: common individualizing characteristic