AI-ASSISTED LITERATURE REVIEW OF THE APPLICATION OF NON-DESTRUCTIVE SPECTROSCOPIC TECHNIQUES IN FORENSIC DOCUMENT ANALYSIS

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INTRODUCTION

Forensic Sciences and Artificial Intelligence (AI)

→The literature review is essential for the scientific framing of research.

→The exponential increase in publications makes manual analysis time-consuming and complex.

→AI tools make it possible to optimize the screening and synthesis of scientific literature.

→AI acts as support for the researcher, not replacing human critical analysis.

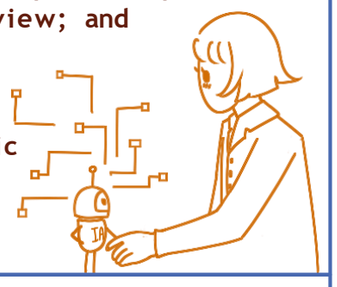
OBJECTIVE

Is Artificial Intelligence useful for scientists' research?

The objective of this work is twofold:

(i)to evaluate the contribution of Artificial Intelligence to the organisation, screening and synthesis of the bibliographic *corpus* in an AI-assisted literature review; and

(ii)to conduct a comprehensive bibliographic review of non-destructive spectroscopic techniques applied to forensic document analysis.



METHODOLOGY

1 Definition of the search strategy

ChatGPT

→The topic under study was provided to ChatGPT and the study objective was defined.

→It was asked how AI could be used for bibliographic research and which tools would be useful to support this research process.

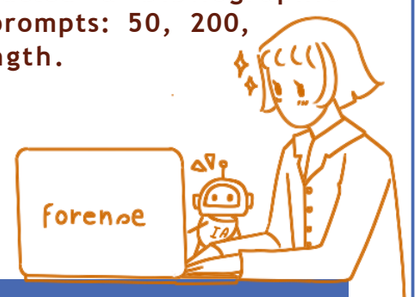
→Finally, assistance was requested in developing a prompt to be used in the provided AIs.



2 AI-assisted bibliographic search

ChatGPT / Bohrium / AI2 Paper Finder

→ To assess the effect of prompt length, the AI models conducted a bibliographic search using three prompts: 50, 200, and 700 words in length.



3 Seleção de artigos

Human + NotebookLM

→Using NotebookLM as a support tool in analysing the provided articles, the contents were evaluated in order to select articles with:

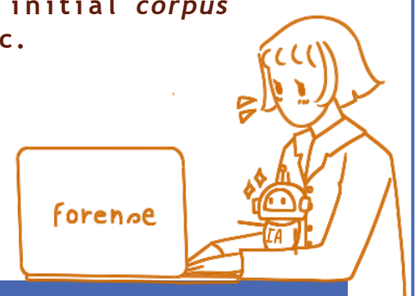
- Thematic relevance;
- Forensic context.



4 Complementary search

ChatGPT / Bohrium / AI2 Paper Finder

→ The search was repeated with new prompts developed with the same objective, in order to enrich the initial *corpus* and deepen the topic.



5 Final bibliographic *corpus*

Microsoft Excel

→Organization of the selected articles.



6 Literature review and scientific framework

Microsoft Excel

→Information extracted from articles, organized by:

- Techniques;
- Analysis targets;
- Forensic area;
- DOI;
- Year.



RESULTS AND DISCUSSION

Non-destructive spectroscopic techniques (review)

Scientific articles from 2010 to 2024:
- 16 articles are experimental studies
- 5 reviews
- 2 case studies
- 2 method development studies

Analytical technique	Category	Frequency (%)	Analysis targets	DOI / Reference
Reflectance / VSC / MSP (includes UV-Vis-NIR)	Optical	44% (11)	Chromatic discrimination, metamerism, security elements (UV/IR), and chromaticity values.	10.1515/acs-2015-0031; 10.1177/0960336021100375 7; 10.1016/j.forsciint.2013.07.017; 10.5935/0103-5053.20140140; 10.1016/j.microc.2014.05.013; 10.1088/1742-6596/249/1/012060; 10.4172/2157-7145.1000329; 10.1016/j.forsciint.2011.09.015; 10.1016/j.optlastec.2020.106704; 10.3390/jimaging6050029; 10.3390/j6040035
ATR-FTIR / FTIR (includes Micro-ATR, ATR-IR)	Vibrational	36% (9)	Molecular structure, paper components (cellulose, lignin), ink dating, and oxidation.	10.1016/j.fsir.2020.100162; 10.22146/ijc.72282; 10.15376/biores.19.1.160-182; 10.1177/0960336021100375 7; GU J Sci 25(2):371-375; 10.1016/j.forsciint.2013.07.017; arXiv:1910.08993; 10.1111/1556-4029.12405; 10.1016/j.optlastec.2020.106704
Raman spectroscopy (includes SERS, Confocal, FT-Raman)	Vibrational	36% (9)	Pigments, dyes, resins, and cross-section sequencing of features (depth profiling).	10.1177/0960336021100375 7; 10.3390/j6040035; 10.3390/msf2023022029; 10.1134/S106193481607011X; GU J Sci 25(2):371-375; 10.1016/j.forsciint.2013.07.017; arXiv:1910.08993; 10.1039/C6A 02340A; 10.1007/s00339-016-0494-9
Hyperspectral Imaging (HSI)	Imaging	24% (6)	Ink mismatch, chemical mapping, fibre morphology, and forgery detection.	10.3390/jimaging6050029; 10.1039/c4an00961d; 10.1109/ICDAR.2013.179; 10.1007/s00339-016-0494-9; 10.1016/j.aej.2023.11.040; 10.1039/C6A 02340A
XRF / EDXRF (X-ray Fluorescence)	Atomic	16% (4)	Elemental composition, metallic ions (Fe, Zn, Ti), and inorganic fillers in paper/pigments.	10.15376/biores.19.1.160-182; 10.1016/j.forsciint.2013.07.017; arXiv:1910.08993; GU J Sci 25(2):371-375
Mössbauer spectroscopy	Nuclear	4% (1)	Oxidation state of iron in pigments and chemical stability in banknotes.	arXiv:1910.08993
Nano-FTIR (AFM-IR / SNOM)	Nanoscale	4% (1)	Nanometre-scale resolution for the assessment of signatures and overlapping features.	10.1016/j.optlastec.2020.106704

→**Evolution and techniques:** Forensic document analysis has evolved from visual methods to non-destructive scientific techniques, such as Raman, ATR-FTIR, HSI, AFM and VSC/MSP, enabling the analysis of substrate characteristics, inks, signatures and traces, embossed seals, among other features, without damaging the documents.

→ **Most widely used techniques:** VSC (UV-Vis-IR) for detecting alterations; Hyperspectral Imaging for ink differentiation; ATR-FTIR and Raman for chemical characterisation of papers and inks; and UV-Vis-NIR for analysing the optical properties of materials.

→ **Machine Learning:** Combining spectroscopy with chemometrics and machine learning (PCA, PLS-DA,CNN) increases precision, objectivity and automation, enabling rapid screening of large volumes of data.

→ **Trends and limitations:** The future points towards miniaturisation of portable equipment, multimodal analysis and digital documents. Current limitations include the scarcity of standardised databases, low sensitivity in distinguishing similar materials and the predominance of laboratory-based studies.

CONCLUSION

- 25 relevant scientific articles
- Useful AI tools, with limitations
  - Reduction of research time
  - Scientific articles aligned with the topic
  - Assistance in selecting the most relevant articles
  - Reduction of bibliographic review overload
  - Risk of omission of non-indexed literature
- Human critical evaluation remains essential
  - To validate results
  - To interpret contexts
- A hybrid model is essential
  - Combines AI productivity with the rigour and contextual analysis of the researcher

AI complements, but does not replace, the role of the scientist, making the review faster and more comprehensive.

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