Artificial Intelligence for Calligraphic Writer Identification: The Case of Lope de Vega's Autographs

Inteligencia Artificial para la identificación caligráfica: el caso de los autógrafos de Lope de Vega

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Abstract. This paper presents a computational approach for detecting the calligraphic footprint of a scribe in a large documentary corpus. The system leverages advances in HTR (Handwritten Text Recognition) techniques, usually employed for automatic transcription, but on this occasion used to locate the specific handwriting

This study was conducted as part of the project titled «HEURESIS: The Creation of the Literary Text: Authors, Manuscripts and New Technologies» (2021 SGR 00191) funded by the Government of Catalonia, the project titled «La Integral Dramática de Lope de Vega: textos, métodos, problemas y proyección» (PID2021-124734NB-I00), funded by the Spanish Ministry of Science and Innovation, by the project titled «Thal-IA: Patrimonio teatral áureo: inteligencia artificial y fotografía espectral», funded by the 2023 call for Grants to Incentivise Research Consolidation (CNS2023-145014), and a Juan de la Cierva postdoctoral grant (JDC2022-050073-I).

of interest when dealing with an extensive collection of texts, in which there may be dozens or even hundreds of different hands. We conducted a control experiment with Lope de Vega (a renowned 17th-century Spanish playwright) and the Transkribus platform (user-friendly for researchers who are not computer specialists), obtaining very accurate results: once trained on Lope's hand and on two hundred other distinct hands, the system can single out Lope's handwriting in documents beyond the model, with high success rates (accuracy, precision, recall, and F1 scores in the range of 0.95-1.00). These findings pave the way for training models for hands of particular interest (authors, censors, copyists, bureaucrats, actors, etc.) and systematically scanning extant documents in order to detect other instances in which they participated, which could lead to discoveries of historical, literary, and patrimonial significance.

Keywords. Hands Detection; Neural Networks; Transkribus; Handwriting Text Recognition; Machine Learning; Spanish Early Modern Manuscripts; Autographs; Lope de Vega; Digital Humanities.

Resumen. Este trabajo presenta una vía computacional para la detección de la huella caligráfica de un escriba en un conjunto documental amplio. El sistema hace uso de los avances en técnicas de HTR (Handwritten Text Recognition), habitualmente empleadas para la transcripción automática, pero utilizadas en esta ocasión para localizar las manos de nuestro interés al lidiar con un grupo extenso de textos, en el que pueden existir decenas o cientos de manos diferentes. Llevamos a cabo un experimento de control con Lope de Vega (reconocido dramaturgo español del siglo xvii) y la plataforma Transkribus (de fácil uso para los investigadores no especialistas en informática) con resultados muy acertados: el sistema, una vez entrenado con la mano de Lope y otras doscientas manos diferentes, es capaz de señalar a Lope en documentos fuera del modelo, con unas tasas de acierto elevadas (exactitud, precisión, recall y puntaje F1 en entorno de 0.95-1.00). Estos resultados abren la puerta a entrenar modelos para manos de relevancia (autores, censores, copistas, burócratas, actores, etc.) y a realizar batidas por los documentos conservados con el fin de localizar otros testimonios en los que hayan intervenido, lo que puede conducir a hallazgos de valor histórico, literario y patrimonial.

Palabras clave. Detección de manos; redes neuronales; Transkribus; reconocimiento de escritura; aprendizaje automático; manuscritos del Siglo de Oro; autógrafos; Lope de Vega, Humanidades Digitales.

Introduction

In 1903, in an exchange of letters with Marcelino Menéndez Pelayo, the expert on Hispanic literature James Fitzmaurice-Kelly raised doubts about the authenticity of certain Lope de Vega autographs held in the British Library[1]:

1. He was referring to manuscripts of *Lo que ha de ser*, *La competencia de los nobles*, *El Argel fingido* and the religious auto *El yugo de Cristo*.

> These are nothing more than copies. I admit that my opinion, on its own, bears little weight in such a debate. Consequently, I brought these 'autographs' to the attention of my friends Mr Warner and Mr Bickley, the current heads of the Manuscripts section at the Museum, both of whom are —naturally— highly skilled in these difficult matters of palaeography, handwriting, etc. As expected, they both initially mocked and scorned my scepticism, defending the infallibility of their field and the catalogue. They did so, undoubtedly, as part of their official duty. But their arguments were really rather weak; the strongest being the authority of La Barrera (*Catálogo*, p. 434). It is highly likely that La Barrera never had the occasion to view these manuscripts in person. Be that as it may, in the end, after a meticulous examination of said 'autographs', Warner and Bickley became convinced that the catalogue was mistaken, and that these four manuscripts are indeed mere copies[2].

This letter explains how the error in La Barrera's catalogue was detected. This may seem like no more than an anecdote that, had it not been corroborated, would have persisted until someone else with the same scepticism and rigorous approach as Fitzmaurice-Kelly eventually noticed it. However, in the case of autograph manuscripts, whether due to lack of expertise or ignorance, catalogue descriptions are not always accurate. The case presented here could easily be extended to other texts that, for one reason or another, have been or continue to be described as autographs. For example, it is common for critics to refer to printing licences and privileges for *Don Quijote* as holographic documents by Miguel de Cervantes when, in actual fact, and as explained by Fernando Bouza Álvarez when he discovered the text in the National Historical Archive of Spain (*Consejos*, Doc. 1159), it is a document written by the pen of the bookseller Francisco de Robles[3]. Another striking case is that of Gaspar de Ovando, a Golden Age playwright about whom nothing is known and whose name only appears when signing a theatrical manuscript titled *La Atalanta* (BNE, 15.509). Nevertheless, published studies unanimously consider this work to be an autograph.

Undoubtedly, from a philological perspective, holographs are fascinating because they take us closer to the process of creating the literary text. These manuscripts preserve the playwright's own corrections, their *pentimenti*, their revisions, and provide a text of unparalleled critical quality. Furthermore, their pages also contain notes attesting to the intervention of other agents in the theatrical network, such as censors, playwrights, prompters, and so on. Ultimately, an autograph is the most useful document for reconstructing the life, movements and modifications of a text.

It may be tempting to say that one possesses an autograph document, but verification of such claims is not always an easy endeavour. How many experts could recognise the handwriting of Calderón, Cervantes, Lope, Tirso de Molina, Claramonte, Vélez de Guevara, Zayas, or Ruiz de Alarcón? The Golden Age produced an abundance of theatrical works, comprising over 3,000 major plays (*comedias* and *autos*) by more than 400 authors, as well as an indeterminate number of scribes, prompters, playwrights and censors. Indeed, a veritable ocean of manuscripts in

2. Letter from James Fitzmaurice-Kelly to Marcelino Menéndez Pelayo, London, 29 June 1903 (Menéndez Pelayo, *Epistolario*, vol. 7, letter 36).
3. The only part of the document that is in Cervantes' handwriting is the signature.

thousands of different intermingled scripts. In this jungle of documents, housed in various libraries and archives, how many autographs remain unknown or mis-catalogued, concealed among millions of handwritten pages?

Until now, autograph manuscripts have been detected and catalogued manually, relying on the dedicated efforts of philologists and palaeographers to one or several playwrights. This can be an almost insurmountable task, as it involves learning about the specific characteristics of a given author and having to scrutinise hundreds of thousands of pages with very similar handwriting. What's more, professionals with this level of expertise and availability are far too low in number for the immense volume of material that has been preserved.

In the last one hundred years, there has been a widespread philological tradition of sourcing and cataloguing the autographs of Golden Age theatre, with particular specialisation in certain canonical playwrights. Examples include analyses of Lope de Vega[4], and studies of Calderón[5]. Various digital projects have also been designed to catalogue manuscripts, such as *Artelope*, *Calderón Digital* and AUTESO, while special mention goes to the *Manos* project directed by M. Greer and A. García-Reidy, which has spent decades compiling Golden Age theatrical manuscripts and analysing their calligraphy, albeit always using analogue palaeographic methods and with no automated computerised support.

From transcription to handwriting recognition

In recent years, Handwriting Text Recognition (HTR) techniques have been incorporated into the study of the textual legacy of the Golden Age, the goal being to automatically transcribe both printed and handwritten documents, thus avoiding the immense amount of palaeographic labour that the manual transcription of these materials would require. This entails the use of neural networks that learn to relate the text contained in documents to their graphical representation. By overlaying a sufficient number of examples (anything from dozens to hundreds of thousands might be required), an accurate computer model is achieved that can transcribe a new document correctly [Figure 1].

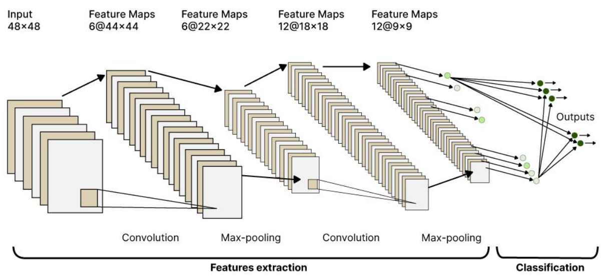
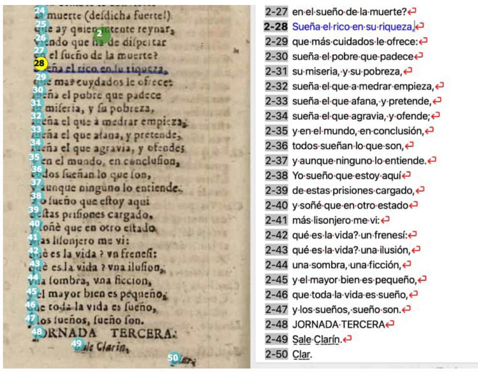


Figure 1. Example structure of a convolutional network (Transkribus documentation)

4. Presotto, 2000; Sánchez Mariana, 2011; Crivellari, 2013 and 2015; Boadas, 2021.
5. Arellano, 2015; Hernando Morata, 2015; Iglesias Feijoo, 2016; Kroll, 2017.

Thanks to these methods, there has been a recent proliferation of models for different periods, languages, and documents[6]. Many of these are created with the Transkribus platform[7], and the Pylaia system[8] that they integrate, because this environment is designed for humanities researchers, who are not usually experts in programming or machine learning. For Golden Age theatre, the context of the experiment conducted in this article, we largely rely on the materials generated by Cuéllar[9], to train models to read printed and handwritten documents from the 16th, 17th, and 18th centuries [Figures 2 and 3].



Figures 2 and 3. Automatic HTR transcriptions of a printed and handwritten document

During this process, it was observed that although transcription models perform better when always transcribing paleographically (without modifications or updates to the spelling and layout of the original documents), they also responded favourably when trained not only to transcribe but also to modernise the spelling. This is because they are not based on specific characters but on sets thereof. It was also noted that the models could recognise whether words in printed documents appear in roman (normal) or italic type and can show this in the transcriptions of new documents [Figure 4].

6. See, for example, the contributions by Sánchez *et al.*, 2014; Hawk *et al.*, 2019; Bazzaco, 2020; Camps *et al.*, 2021; Ayuso García, 2022; Bazzaco *et al.*, 2022; Blasut, 2022; Clérice, 2022; Fradejas Rueda, 2022; Pinche, 2022; Ströbel *et al.*, 2022; Terras, 2022; Couture *et al.*, 2023; Souibgui *et al.*, 2023.
7. Muehlberger *et. al.*, 2019.
8. Puigcerver and Mocholí, 2018.
9. Cuéllar, 2023.

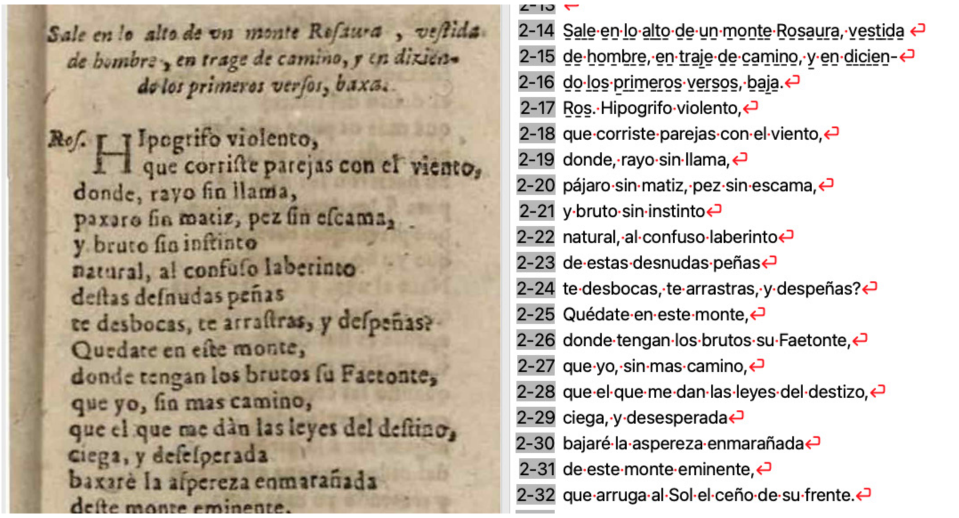


Figure 4. Automatic transcription with italic detection (underlined)

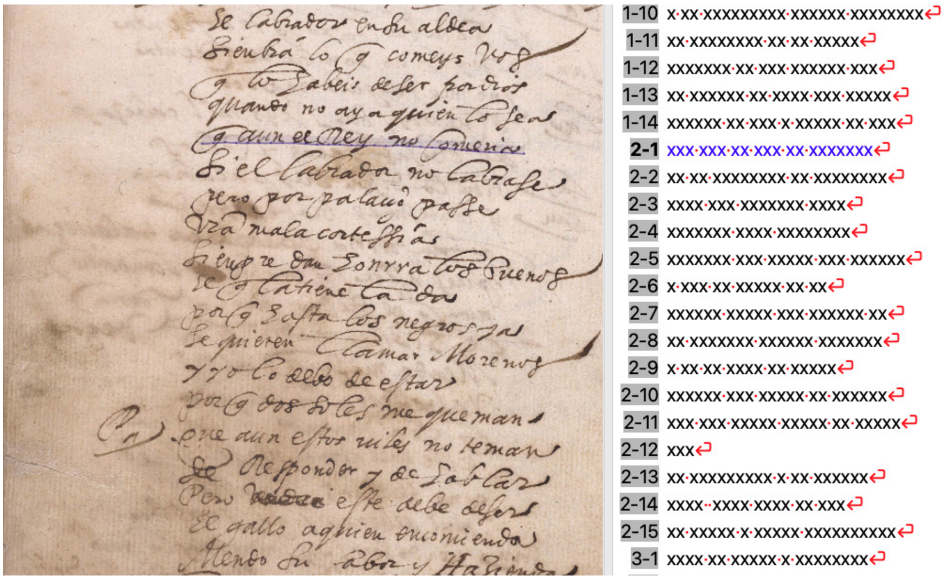
This graphical differentiation in printed texts was fundamental for envisioning new transcription possibilities. Could the model recognise and identify different types of handwritten script? If this capability were to be confirmed, HTR computational techniques could also be used as a kind of calligraphic detector.

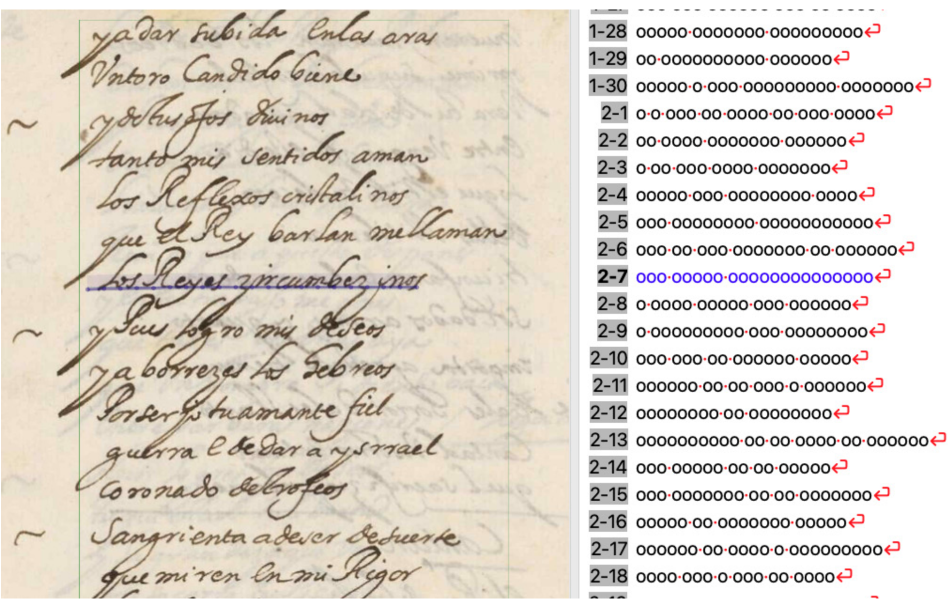
To test the scope and feasibility of this idea, we decided to conduct a pilot test with the handwriting of the playwright Lope de Vega Carpio (1562-1635). This was no random choice, but was based on the large amount of autograph material by the 'Phoenix of Wits' that has been preserved, and the major efforts to catalogue and digitise that material[10]. Could the program identify Lope de Vega's own hand out of thousands of handwritten images?

The *LopeDetector*

The starting point for the experiment was to adjust Transkribus' usual training process. Instead of teaching the model to associate each stroke with a specific letter to transcribe a text, we trained it to assign a symbol (such as a letter of the alphabet) to the different hands in the manuscripts. We instructed it to use the letter X to transcribe manuscripts written in Lope de Vega's handwriting, and the letter O for the handwriting of other authors. Hence, the machine learned to distinguish the playwright's distinct handwriting from any others [Figures 5 and 6]. Naturally, when the model encounters new documents, it will transcribe using one symbol or the other, depending on whether it identifies the handwriting as Lope's or not. We believe that the binary nature of the assigned task (Lope's hand vs. Not Lope's hand) helps to minimise noise and added complications in the process.

10. For the cataloguing and location of Lope de Vega's autograph manuscripts, see Crivellari, 2015; Presotto, 2000.





Figures 5 and 6. Transcriptions of Lope and Non-Lope handwriting

Having established the training method, we gathered the corpus of texts to train and test the model. We used 39 manuscripts directly penned by Lope de Vega himself[11] and 223 manuscripts in different handwriting[12]. The documents came from different institutions (National Library of Spain, the British Library and the Theatre Institute of Barcelona, among others), had been digitised by means of different processes (high-res professional reproductions, black-and-white images, or photographs taken with the researchers' own cameras, etc.), and had not been processed or homogenised in any way (in fact, some were single-sided while others were printed on both sides). In other words, the materials were not especially prepared for the experiment, and the test was conducted in a real-world environment to avoid bias.

We divided the works into five subsets to perform five-fold cross-validation. We trained five different models; in each iteration, four subsets were used for training and one for validation. This process was repeated until each subset had been used once as the validation set. Hence, the entire corpus was evaluated, ensuring that specific documents with exceptionally positive or negative results did not unduly influence the model's perceptions.

To test the models in each case, we balanced the number of examples from Lope de Vega's handwriting with those by other hands. This meant we could assess the model's performance more accurately and fairly, avoiding skewed results due to the larger number of non-Lope documents. The metrics used for evaluation included *precision* (how accurate the model's positive predictions are), *recall* (the proportion of true positives out of all cases that really are positive cases[13]), *exactness* (the overall performance of the model across all classes), and the *F1 score*,

11. The autographs used for training were: *Amor con vista; Amor, pleito y desafío; Ay verdades que en amor; El bastardo Mudarra; La batalla del honor; Las bizarrías de Belisa; El Brasil restituido; El cardenal de Belén; Carlos V en Francia; El castigo sin venganza; La corona de Hungría; La corona merecida; La dama boba; De cuando acá nos vino; Del monte sale; El desdén vengado; La discordia en los casados; La doncella Teodor; La encomienda bien guardada; Estefanía la desdichada; El galán de la Membrilla; La hermosa Ester; Lo que pasa en una tarde; Más pueden celos que amor; Los melindres de Belisa; La niñez del Padre Rojas; La nueva victoria de don Gonzalo de Córdoba; Pedro Carbonero; El piadoso aragonés; El poder en el discreto; El primero Benavides; El príncipe despeñado; La prueba de los amigos; Quien más no puede; Santiago el verde; El sembrar en buena tierra; Sin secreto no hay amor; Vida y muerte de Santa Teresa de Jesús* (BNE and Parma). For the location of all these documents, see Presotto, 2000.

12. It is hard to determine the exact number of hands other than Lope's contained in these documents, as a specific palaeographic study would be needed for each one. Several manuscripts may share the same hand, and different hands may coexist within a single work. We roughly estimate that there must be around 100 to 300 hands other than Lope's in these materials.

13. In the confusion matrices, the True Positives (TP) represent Lope de Vega's calligraphic characters that are correctly classified; the False Positives (FP) represent his characters that are incorrectly classified; the False Negatives (FN) represent the characters by other hands that are incorrectly classified; and the True Negatives (TN) represent the characters by other hands that are correctly classified.

which provides a balance between these metrics. The closer this score is to 1.0, the better the results are. The average error rate per character after combining the data from the five groups is as follows[14]:

Figure 7. Confusion Matrix Average: Precision: 0.98 / Recall: 0.99 / Exactness: 0.99 / F1 Score: 0.99

As shown, the results were excellent in all cases, achieving near-perfect detection of Lope's handwriting as opposed to that of other authors. The errors are mainly associated with crossed-out lines or deteriorated pages [Figure 8]. We identified a few other instances where, for unknown reasons, the model failed to correctly identify the handwriting [Figure 9], but these were individual verses or isolated annotations.

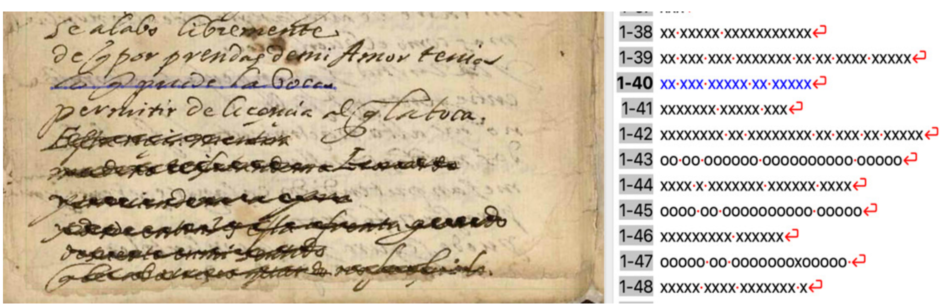


Figure 8. Noise in the detection due to a deteriorated document

14. The following are the results of the five confusion matrices. Group 1: TP. 99058; FP. 2292; FN: 2695; TN: 85352. Precision: 0.98; Recall: 0.97; Exactness: 0.97; F1 Score: 0.98. / Group 2: TP. 76692; FP. 1397; FN: 718; TN: 97754. Precision: 0.98; Recall: 0.99; Exactness: 0.99; F1 Score: 0.99. / Group 3: TP. 88886; FP. 1792; FN: 356; TN: 87773. Precision: 0.98; Recall: 1.00; Exactness: 0.99; F1 Score: 0.99. / Group 4: TP. 79519; FP. 699; FN: 351; TN: 86792. Precision: 0.99; Recall: 1.00; Exactness: 0.99; F1 Score: 0.99. / Group 5: TP. 65894; FP. 1590; FN: 243; TN: 94241. Precision: 0.98; Recall: 1.00; Exactness: 0.99; F1 Score: 0.99.

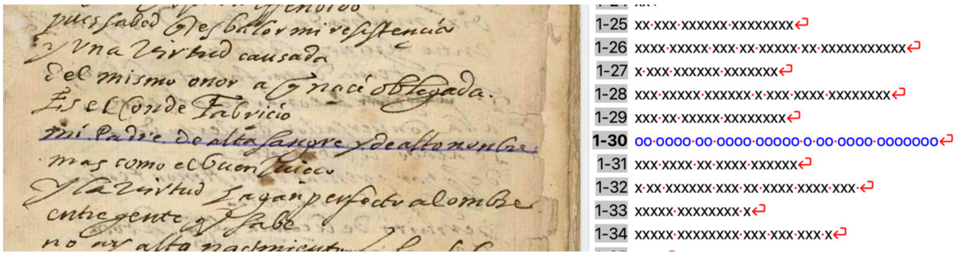


Figure 9. Failure to detect Lope's handwriting for unknown causes

Therefore, the system is not designed to determine whether a specific word or line pertains to one scribe or another but rather to detect a set of lines or pages written by a particular author within a larger document that might otherwise go unnoticed. When classifying pages or even entire works based on the detected handwriting, we achieved practically 100% accuracy across all cases of our experiment.

Using all these materials, we built the *LopeDetector* model within the Transkribus environment[15]. Its training dataset comprised 2,897,977 words (926,425 lines). The model is able to assign a symbol ('X' or 'O') depending on whether it is Lope de Vega's handwriting or not, and its learning curve is displayed on the platform as follows[16]:

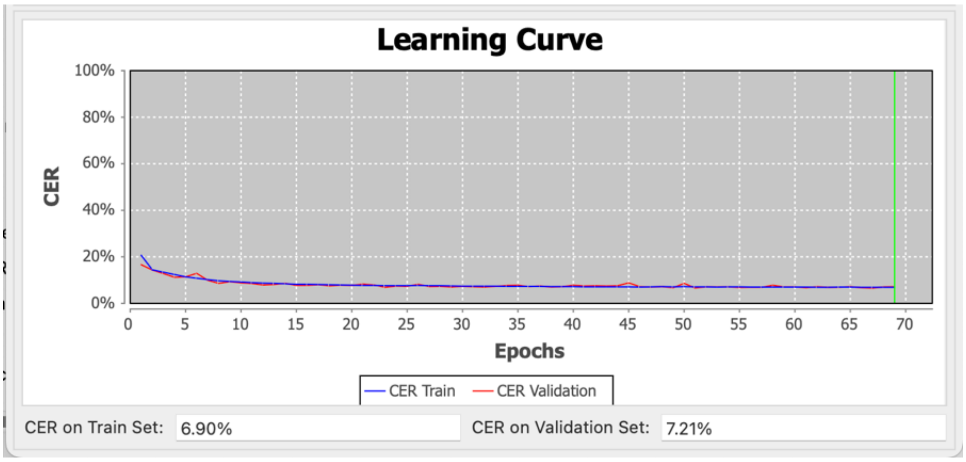


Figure 10. Learning curve of the *LopeDetector* model

15. We make the *LopeDetector* model available to users through the Transkribus platform so that the research community can use, replicate, and improve it. All the materials used for training can also be downloaded from the platform (or are available on request from the researchers).
16. Although the Transkribus platform provides its own Character Error Rate (CER) for the model, we felt it would be safer to rely on our specific validations, in which we tested the model not only with pages that were not part of the training set, but also with works that the systems had not encountered in each case.

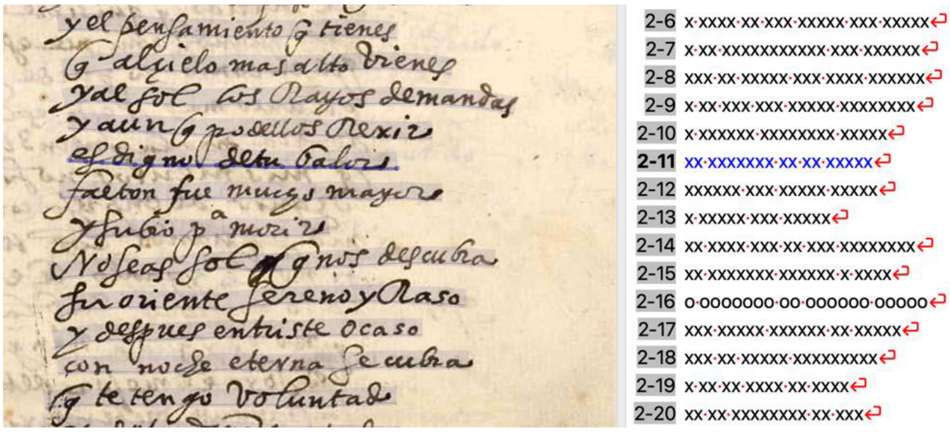
To further validate these results, we applied the *LopeDetector* model to 54 new manuscripts that were not included in the initial sample. This new corpus consisted of four Lope autographs and fifty manuscripts penned by other authors[17]. The external validation test yielded the following results:

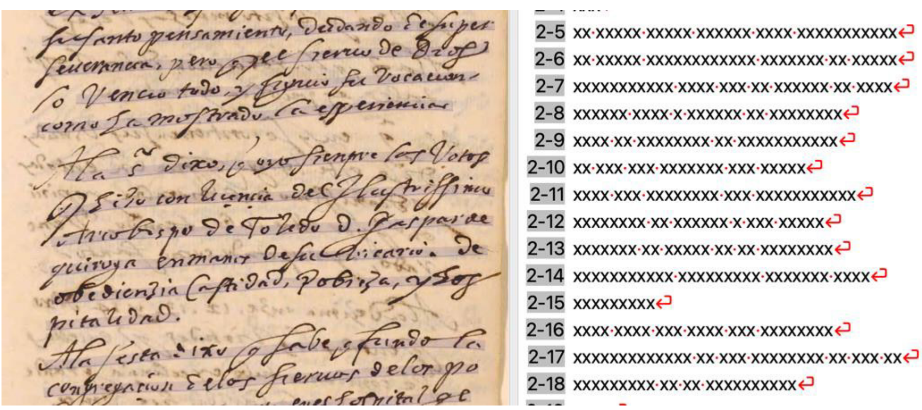
Figure 11. Confusion matrix. External validation: Precision: 0.99 / Recall: 0.95 / Exactness: 0.97 / F1 Score: 0.97

The results of the external validation test were highly satisfactory, and that was despite the challenges posed by the poor digitisation of one of our Lope manuscripts, *El caballero del Sacramento*.

At this point, we decided to further test the reliability of the *LopeDetector* model by finding out whether it could identify Lope de Vega's handwriting when there were slight variations or in different contexts from those of the training manuscripts. We selected three texts with peculiarly distinctive calligraphic features: the play *El favor agradecido* (1593), one of the earliest autographs we have and where the handwriting is slightly different from his later manuscripts; the *Códice Daza*, a notebook containing autograph drafts, often scribbled quickly with a lot of crossing out; and a volume of prose correspondence that Lope wrote for the Duke of Sessa[18]. In all three cases, the results were highly positive:

17. The autograph manuscripts that made up this corpus were *Barlaan y Josafat*, *El caballero del Sacramento, El cuerdo loco* and *El marqués de las Navas*.
18. The full references to the manuscripts are as follows: *El favor agradecido* (BNE, Res/134), *Códice Daza* (BNE, Res/284), *Cartas y billetes de Belardo a Lucilo sobre diversas materias* (BNE, Res/298).





Figures 12, 13 and 14: Automatic detection of excerpts from *El favor agradecido*, the *Códice Daza*, and Lope's correspondence

The *LopeDetector* has no trouble correctly identifying Lope's handwriting in prose texts (94.06% of the work is accurately classified), nor in the sheets of the *Códice Daza* (98.20% classified correctly). In the case of the play *El favor agradeci-*

do, the calligraphy of a younger Lope de Vega's handwriting yields a somewhat lower accuracy rate of 89.5%, although this is still a very high percentage[19]. While the detector was not quite so successful in these cases as in the manuscripts used for validation, we were able to confirm that it nevertheless has little difficulty identifying Lope's handwriting across different contexts and with slight variations.

These experiments demonstrate that HTR systems can be used not only for transcription, but also to detect a specific writer's handwriting with high accuracy rates. Lope de Vega is an especially appropriate subject for such tests, given that we have tens of thousands of pages written by the author. It would be useful to work out the number of lines required for the system to function reliably, in order to detect the handwriting of authors for whom fewer autographs have been preserved (such as Cervantes, Rojas Zorrilla, María de Zayas and Tirso de Molina). We intend to address that challenge in future studies. It would also be useful to move future models outside of the Transkribus environment, as use of the platform to track an author's handwriting across tens or hundreds of thousands of manuscript pages would be prohibitively expensive.

Future research directions

Thanks to this satisfactory control experiment, we have launched the Thal-IA project, the goal of which is to understand the collaborative relationships between the different agents of the theatrical landscape (playwrights, company directors, censors, actors, etc.). This endeavour necessarily entails cataloguing and studying the autograph manuscripts of Golden Age playwrights.

While some authors, such as Lope de Vega and Calderón de la Barca, have been extensively studied, there is a myriad of playwrights who have not received as much attention. Although the main catalogues have been scanned for autographs of the biggest names, archival collections have not been scoured to the same extent in search of lesser-known writers, whose handwriting tends not to be so accurately known. Moreover, a manual collation of thousands of manuscripts would require an effort of impossibly titanic proportions. An expert palaeographer cannot feasibly classify the dozens, hundreds, or even thousands of calligraphies that appear in all those documents. Furthermore, far too few professionals have sufficient training and availability to tackle the immense volume of materials we possess, literally thousands of documents written by hundreds of different hands. The application of Artificial Intelligence to recognise handwriting can enhance and scale these investigations to unprecedented levels. The aim of the first phase of the project is to train the model to recognise around 100 hands, and to search for them in at least 15,000 manuscripts. After this detection process, the definitive palaeographic collation will always be performed by a qualified researcher to verify the AI's findings. The machine will thus serve as a detector, noting cases of interest for subsequent manual verification.

19. For the palaeographic study of this manuscript, see Cuenca, 2021.

James Fitzmaurice-Kelly, the expert on Hispanic literature whose letter to Marcelino Menéndez Pelayo was quoted at the beginning of this article, drew attention to the difficulties of working with holographic materials: «In this question of autographs, mistakes are very easily made»[20]. And he was quite right. However, modern-day researchers who wish to study theatrical autographs now have a tool at their disposal that can facilitate the identification of Lope de Vega's handwriting.

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