UMR IRISA

Activity Report 2023

Team SHADOC

Systems for Hybrid Analysis of DOCuments

D6 – Signal, Image, Language

Team INTUIDOC Activity Report (1/01/2023 - 29/6/2023)
Team SHADOC Activity Report (30/6/2023 - 31/12/2023)

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1 Team composition

Researchers and faculty

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Hugo Hazard, Insa Research Engineer
Bruno Hortollary, Insa Research Engineer, from October 1st
Ali Yesilkanat, Insa Research Engineer
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PhD students

Islam Barchouch, Insa PhD student
Killian Barrère, Insa PhD student until 31st August; Assistant Professor (ATER), ENS, since 1st September
Simon Corbillé, Univ. Rennes PhD student, until June 30th
Martin Dornier, CIFRE/Insa PhD student, until September 30th
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2 Overall objectives

2.1 Overview

The Shadoc team focuses on *modelling man-made data for written communication*: handwriting, gesture (2D and 3D), and documents, under various aspects: analysis, recognition, composition, interpretation.

The objective is to achieve a continuum between paper and digital documents with a certain readability. We mainly focus on the following topics:

- Intelligent recognition of handwritten content: documents, writings, gestures;
- Analysis of the semantic/structural content: document structure, stages of production of diagrams, drawings, musical scores, sketches, architectural plans;
- Design of new AI, combining recognition and analysis: offer enriched experiences for digital humanities or e-education.

The roadmap of the Shadoc team is on the frontier of several research axes: Pattern Recognition, Machine Learning, Artificial Intelligence, Human-Machine Interaction, Uses and Digital Learning.

Our research is characterized by the hybridization of several AI approaches: two-dimensional grammars, deep learning, fuzzy inference systems... This hybridization aims at guaranteeing, beyond performance, important aspects such as: explicability, genericity, adaptability, data frugality.

Beyond hybridization, the originality of this research is to focus on user interaction. This strategy aims at answering the limits of the current approaches which are based on non-interactive treatments. The concept is to reinforce the decision processes by relying on the implicit validations or explicit corrections of a user to avoid the propagation of errors throughout the analysis. The notions of interpretation, adaptation and incremental learning are at the heart of this research, the objective being to design efficient, robust and self-evolving systems.

The studied data take two main aspects: image recognition and analysis of sequences (time series) in different forms, from sensor signals to document collections.

Image recognition The first field of interest is image recognition of documents. Nowadays, some commercial OCR (Optical Character Recognition) systems are available for automatic document recognition. However, those systems present their limits for the recognition of ancient, handwritten or heterogeneous documents. We work on scanned images of historical and recent documents with complex structures. We also consider digital native documents, such as PDFs, the structure of which is not always directly interpretable.

Analysis of Sequences / Time series The team works on time series and information sequences in the field of analysis, interpretation and recognition according to several granularities and modalities.

We consider first of all low-level time series associated with trajectories formed by handwritten traces or 2D/3D gestures. They come from different types of sensors: inertial, Pen-based and (Multi-)Touch Capture on touch screen, Motion capture, Kinect or Leap Motion sensor. The objective here is the reconstruction, analysis, synthesis or interpretation of these time series, like for on-line handwritten scripts recognition [R9, R13]. Handwritten text recognition in document images are also processed sequentially and considered as time series [R2, R3].

At a higher level, time series are studied to provide context (temporal, spatial and semantic) and to develop evolutionary or incremental analysis and learning approaches. The objective is for instance to detect concept changes in a data stream (a sequence of documents, a sequence of gestures, or more generally a sequence of actions) in order to adapt recognition models to concept drift [R11, R6]. Another concept is for example to design an on-the-fly analysis of a document composition (stroke by stroke) [R7].

We can also consider many sequences in collections of documents. Thus, with historical degraded documents, it is sometimes possible to improve the recognition using other pages of the document, when some information is repeated on different pages of the collection. We proposed to work in an original way by automatically transforming the different unit data (like text fields, titles, column widths...) found on the pages of a collection of documents, into different sequences of these unit data. These sequences are then analyzed for stabilities and breaks, in order to use the context of a collection of documents to improve the recognition quality [R1].

2.2 Scientific foundations

2.2.1 Combination / Hybridization

In the field of document recognition, recent approaches based on deep learning have shown results that outperforms the state of the art. However, those approaches present two main limitations: first, they require a large amount of labeled data for training; second, the trained systems can be seen as black boxes, and the results are often difficult to interpret and correct.

On another hand, the previous Intuidoc team has been working for a long time on the development of two-dimensional grammars that enables a physical, syntactic, and semantic description of the contents. The interest of these syntactical approaches is that they do not require labeled data for training.

The originality of Shadoc team is to propose a combination between deep learning based systems and syntactical ones. We study different implementations of combination:

- The syntactical part brings contextual information to generative neural networks to make them able to converge [R4];
- Some low level elements can be extracted using deep learning systems: text-lines, simple gestures, symbols... They are then combined using two dimensional grammars. This type of combination builds hybrid systems with greater generalization capabilities than neural-only systems, while requiring a smaller amount of annotated data [R10];

- Combination of document structure recognition and handwriting recognition;
- Combination of syntactical language models with transformers neural networks [R15];
- Combination of handwriting recognition with explicit segmentation with Seq2Seq recognition [R8].
- Strong combination of two dimensional grammars and transformers, where syntactical rules drives the transformer architecture.

This exploration of different mechanisms of combination between syntactic and neural models allows to reduce as much as possible the expression of a priori knowledge in syntactic form on elements that are difficult to learn for deep neural networks (or at the cost of very large amounts of annotated data), while taking advantage of the modeling capabilities of deep learning on elements that require less annotated data. This is a way to simplify the adaptation of a system to a new corpus, while increasing its generalization capabilities. Another interest of using combined approaches is to keep the systems interpretable. We can also formalize how the user interaction and the recognition system combine to keep the human in the loop.

2.2.2 Learning with few data

Deep learning methods become state-of-the-art approaches for many tasks. This is the case in the field of the Shadoc team for online and offline handwriting recognition and document image analysis. As discussed before, such methods are widely explored in many of ours works. However, such models require a lot of training examples to perform well.

Learning with few data is a regular limitation in our applications. On the one hand, works of the team are done with humans. Thus, data have to be acquired with users, which limits the amount of data that can be acquired. In particular, recently, several projects have been done in the team for students and doing data acquisition in schools is not easy for various reasons. On the other hand, other works of the team are focused on historical documents such as register, journals, books ... Having labeled examples related to the document is difficult as it may be hard to annotate examples, even if the user is an expert of the domain. This may be due to the old language, the handwriting style, or degraded documents. Thus, one has to deal with only a limited amount of labeled examples.

Various approaches can be investigated to overcome this limitation. One way is to design network architectures which build a relevant latent representation of data, even if it is trained on a small training set [R5]. Another way is to design a semi-supervised approach. These approaches allow to benefit of large set of unsupervised data when only a small amount of labeled examples is available. The users can be involved in the labeling process through a semi-automatic approach, called active learning, for which a model selects data examples of interest which will be manually labeled by the user [R11].

Those approaches can be combined with syntactical methods that do not require label data. The syntactical methods can be used to model the need of interaction when content recognition requires the intervention of an expert. They can also give the contextual information needed by generative neural networks (like IsolatingGAN, see section 2.2.3) to automatically generate labeled data of symbols [R4].

2.2.3 Self-adaptive systems

Building self-adaptive systems which can automatically adapt themselves to a new corpus of document without any or with only few labeled data is a challenging objective. It can be reached by combining syntactic and unsupervised deep learning methods. We propose to first work on a self-adaptive system for Optical Music Recognition (OMR) capable of improving its performance on degraded old scores. This method will be built on the IsolatingGAN [R4] proposed in a previous PhD work of the team where the GAN generator is able to generate labeled data of musical symbols on real images using only unlabeled musical scores and examples of isolated symbols. With this data, the system will be able to adapt to the unlabeled corpus by successive unsupervised learning, producing annotated data with the IsolatingGAN. These automatically annotated data can then be used to adapt the musical symbol detectors.

The driving of these auto-adaptation mechanisms to a corpus is possible by using the ISICA method (Interactive Strategy for Iterative Collection Analysis), validated on the European project EurHisFirm and the HBDEX ANR project, on cross-validation mechanisms on a collection of documents, applied to stock exchange quotation lists of the 19^{th} and 20^{th} century [R1]. Thus, at each iteration, a new set of automatically produced annotated data will be built for a subset of musical symbols. This dataset will be used to learn a new detector for this subset of musical symbols. Then this detector will be integrated into the parsing in the next iteration, thus producing the necessary data for a new subset of musical symbols that would not have been accessible in the previous iteration. This progressive iterative process will stop when all classes of musical symbols have been covered. This approach allows self-adaptation on symbols, detected by deep learning.

More and more data are being produced continuously. In order to analyze this data, it is necessary to integrate it continuously, which is often referred to as learning on data streams. The problem is that often the environment can be non-stationary, resulting in concept drifts, or the data stream is potentially infinite, which requires the system not to save the data. We explore different approaches of incremental learning based on evolutionary fuzzy inference systems that have the ability to develop both generative and discriminative modeling. This work will be applied to continuous gesture recognition allowing the user to evolve his gesture set on the fly [R11].

In our work, including those oriented to help learning writing and geometry, the production of feedback is an essential element [R12]. To be relevant, these feedbacks must be personalized, in fact the system must adapt to the current user. In the context of work on learning aid tools, the modeling of the process of solving a problem by knowledge graphs seems to us to be an avenue to explore in order to define new self-adaptive models.

2.2.4 Rejection capabilities

The construction of recognition systems with rejection capabilities is important both for the integration of these systems in interactive processes, with humans or other systems, but also to be able to exploit automatically generated annotations, and integrate them in semi-supervision processes. Indeed it is important to select through rejection, when a human expert will be solicited to answer questions in an interactive system. We will also study rejection capacities of deep neural networks to be able to select unsupervised annotated data to be used as new training data.

For example we will work on rejection in the CollabScore project for building a self-adaptive OMR system and in the ANTAI project on license plate recognition. Rejection capabilities of deep neural networks are also important to build hybrid systems to make decisions at the interface between the syntactic and deep part. Rejection is also necessary for hybrid systems to explain their decisions.

2.3 Application domains

The application contexts are very numerous, which is important to access real and large datasets, with real applications which lead to strong scientific challenges, while studying generic solutions.

Among the different types of documents studied by the team, there are ancient documents. Thus, there are many possible applications with archive services and digital humanities. Depending on the field of application, the analysis can be made in cooperation with various experts: economists, historians, musicologists, geologists, geographers... to work on documents such as administrative archives, musical scores, old newspapers, stock exchange price lists, financial yearbooks, geological section plans... One difficulty for ancient document recognition is that the documents are often degraded, which complicates their recognition. The second limit is that the recognition is often difficult, even for humans, while few labeled data are generally available. The objective is then to design recognition systems for structure and writings, able to be trained with few annotated data and able to improve themselves by self-adaptive recognition mechanisms. Some applications to historical documents require a very high quality of information extraction which implies the development of methods able to reach the best recognition rates in very difficult contexts. One way to improve the recognition quality is to use the sequence of documents and their redundancies which can be found in collections of documents, like in serial documents such as statistical data registers (weather, population), financial documents, administrative records... The collection of documents can also help in reducing the number of user interactions while improving the recognition.

Another type of documents studied by the team are those produced online. For these documents, the objective is to design interpretation systems and intelligent tutors based on artificial intelligence. Some of the online documents studied by the team come from productions written in a school learning context, thus making it possible to innovate in the field of e-education. The work carried out in this area is part of educational innovation projects supported by the academy and the Ministry of Education. We rely on the scientific foundations acquired in the fields of artificial intelligence ("pattern recog-

nition", "machine learning") and human-machine interaction. One of the challenges for education is to guarantee the transferability of the acquired knowledge via the digital solution (tablet) to the traditional use (paper/pencil) and vice versa. For this, we have focused our digital tablet interactions on "pen" interactions to allow the student to write and draw on the tablet as on paper. The objective is to design automated interpretation systems (intelligent tutor) of the students' productions: writing, arithmetic operations, geometric diagrams. This scientific know-how is the basis for the design of new "e-Learning" solutions that will allow more autonomy and personalization in the learning of each student.

The analysis of these online handwritten productions (2D gestures) makes it possible to imagine new gesture-interaction systems, and in particular 3D gesture-interactions. This other field of research interests the team, with the objective to obtain reactive and natural interactions with tactile devices as well as 3D sensor like Kinect. Gesture interaction allows the user to manipulate naturally the device, but they are today often limited to very basic functionalities like zooming, rotating and scrolling. The difficulty of adding new gestures is two folds: recognition accuracy and system reactivity. Increasing the number of gestures increases the probability of having gestures with common beginning. As a consequence, the system cannot predict the gesture from first traces without potentially executing undesirable commands. In this application domain, we design methods for the challenging task of early recognition of untrimmed gestures.

3 Scientific achievements

3.1 Lightweight Transformer-based Architectures for Historical Handwritten Text Recognition

Participants: Killian Barrère, Yann Soullard, Aurélie Lemaitre, Bertrand Coüasnon.

This section presents the works done during the third and last year of this thesis. The works were focused on the recognition of difficult handwritings originating from historical documents with limited annotated data.

Transformer architectures could alleviate many concerns related to historical documents (degradations, specific handwritings for which few examples are available and ancient languages that vary over time), thanks to their ability to have a global view of textual images and their language modeling capabilities. However, they require a significant amount of annotated data to achieve competitive results. in our works, we proposed and studied lightweight Transformer architectures (5–8M parameters) in order to improve the recognition performances. To train these architectures, we introduced realistic looking synthetic data reproducing the style of historical handwritings (Figure 1). We introduced a specific strategy, both for training and prediction, to deal with historical documents, where only a limited amount of training data is available. We evaluated our approaches on the ICFHR 2018 READ dataset which is dedicated to handwriting recognition in specific historical documents. The results show that our Transformer-based approaches is able to outperform existing methods.

These works were presented at SIFED 2023 [15] and accepted in an international

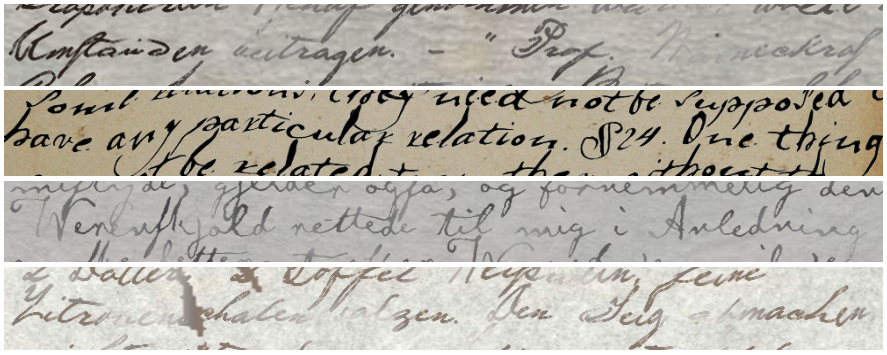

Figure 1: Examples of generated synthetic text-lines, trying to match the style of the ICFHR 2018 READ dataset.

peer-reviewed journal [6].

The thesis of Killian Barrère was defended the 20$^{\text{th}}$ of December 2023 [1].

3.2 Optical Music Recognition of full-page orchestra scores recognition

Participants: Ali Yesilkanat, Hugo Hazard, Aurélie Lemaitre, Bertrand Coüasnon, Yann Soullard, Nathalie Girard, Denis Coquenet.

In the context of Collabscore project (section 5.2.1), we work on Optical Music Recognition (OMR) of orchestra scores. The work is divided in two aspects: the construction of recognizers for musical symbols, based on deep learning, and the grammatical description of musical contents, based on the syntactic DMOS method.

3.2.1 Full-page Musical Symbols Detection

The localization and classification of musical symbols on scanned or digital music scores pose significant challenges in Optical Music Recognition, such as similar musical symbol categories and a large number of overlapping tiny musical symbols within high-resolution music scores. Recently, deep learning-based techniques show promising results in addressing these challenges by leveraging object detection models. However, unclear directions in training and evaluation approaches, such as inconsistency between usage of full-page or cropped images, handling image scores at full-page level in high-resolution, reporting results on only specific object categories, missing comprehensive analysis with recent state-of-the-art object detection methods, cause a lack of benchmarking and analyzing the impact of proposed methods in music object recognition. To address these issues, we perform intensive analysis with recent object detection models, exploring effective ways of handling high-resolution images on existing benchmarks. Our goal is to narrow the gap between object detection models designed for common objects and relatively small images compared to music scores, and the unique challenges of music score recognition in terms of object size and resolution. We achieve state-of-the-art results

across mAP and Weighted mAP on two challenging datasets, namely DeepScoresV2 and the MUSCIMA++ datasets, by demonstrating the effectiveness of this approach in both printed and handwritten music scores.

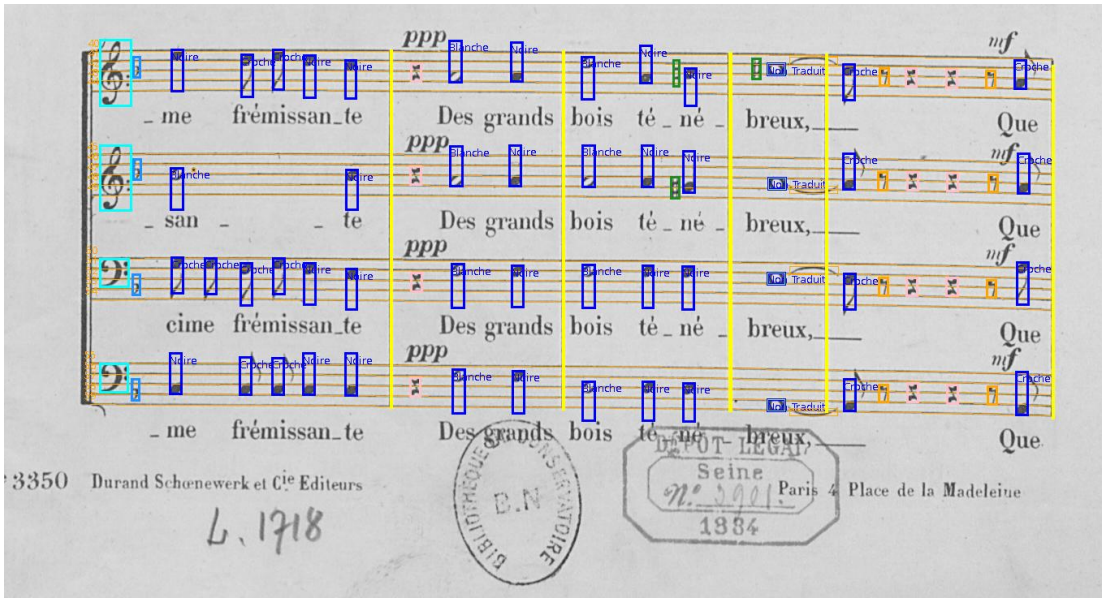

Figure 2: Results of OMR on an orchestra score from "Marin de Kermor", Camille Saint-Saëns.

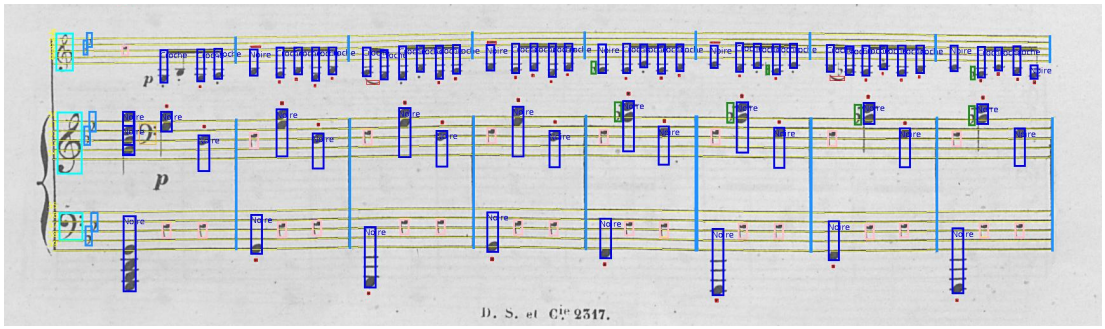

Figure 3: Results of OMR on a score from "Danse macabre", Camille Saint-Saëns.

3.2.2 Grammatical description of musical scores

The grammatical description is based on DMOS method. The terminal elements are composed of vertical segments and connected components from our Music image processing library (Musique). Then the resulting components of the full-page musical symbols detector (section 3.2.1) are added to the list of terminal elements. Using these terminals and after having detected the stafflines (which is another role of the Musique library), the grammatical description of musical notation allow us to recognize a system of staves found in orchestra scores, made of measures with polyphonic voices on single staves, containing headers (clefs, key and time signatures), voice elements (notes,

chords, rests...) and their associated characteristics (accidentals, augmentation dots, dynamics, articulation marks...). The grammatical rules also detects possible inconsistencies in the recognized orchestra score by double checking the global coherence like note duration and their vertical synchronization, voice duration... to avoid a user to check the whole score, which is time consuming. Examples of results are presented in Fig. 2 and in Fig. 3 and To complete this OMR system we will work on lyrics integration and voices going from one staff to another in double staves for piano.

3.3 Knowledge Integration Inside Multitask Network for Analysis of Unseen ID Types

Participants: Timothée Neitthoffer, Yann Soullard, Aurélie Lemaitre, Bertrand Coüasnon, Ahmad Montaser Awal (IdNow).

Identity Document recognition is a key step in Know Your Customer applications where identity documents (IDs) are verified. IDs belonging to the same type share the same field structure called template. Traditional ID pipelines leverage this template to guide the localization of the fields and then the text recognition. However, they have to be tuned to the different templates to correctly perform on those. Thus, such pipelines can not be directly used on new types of IDs. We address the task of text localization and recognition in the context of new document types, where only the template is available with no labeled samples from the new ID type [12]. To that end, we proposed the use of Context Blocks (CB) performing template self-attention to guide the features of the network by the template. We proposed three ways to leverage CB in a multitask architecture. To evaluate our approach, we design a new public task for the MIDV2020 database from rectified in-the-wild photos. Our method achieves the best results for two datasets including an industrial one composed of real examples.

3.4 Sketch - pen-based tutoring system for anatomy courses

Participants: Eric Anquetil, Nathalie Girard, Islam Barchouch, Omar Krichen.

IntuiSketch is pen-based tutoring system for anatomy courses in French university. This work is part of the ANR project "Sketch" (section 5.2.3) led by the LP3C at the University of Rennes 2, for which we are responsible for the IA workpackages.

The objective here is to combine online recognition techniques, that enable to interpret the sketches drawn by the students, with tutoring techniques, that model the domain knowledge. IntuiSketch is able to analyze the student drawings relatively to a problem defined by the teacher, and generate corrective feedback. The online recognition is based on the bi-dimensional grammar CD-CMG (Context Driven Constraint Multiset Grammar) which models the document structure, coupled with a fuzzy incremental classifier, which is able to learn from few examples. The tutoring system is based on constraint modeling, which enables to define domain and problem knowledge, and to analyze the student production relatively to the constraints that have to be satisfied to solve the problem.

In these early works, We define a new architecture for anatomy sketch targeted intelligent tutoring system that combines different techniques. These works were presented at SIFED 2023 [14] and a qualitative study of the feedback that our first system version is able to generate on a case study was presented at IGS 2023 [9].

3.5 Triangle

Participants: Eric Anquetil, Nathalie Girard, Omar Krichen, Sarah Bucquet, Erell Choulette.

TRIANGLE project aims to help students learn geometry in secondary schools. This work is part of the ANR project "TRIANGLE" (e-Fran transfert, section 5.2.4), for which we are responsible for the AI/intelligent tutor workpackages.
The aim is to produce a finished product (IntuiGeo) that can be used in French schools. It includes experimentation and deployment in the Rennes and Poitiers academies.

IntuiGeo is an intelligent tutoring system for geometry learning in middle school. The objective is to combine pattern recognition and tutoring techniques to give real-time feedback for the construction of a geometry problem. We have implemented two kinds of feedback : descriptive and guidance feedback. Both kinds of feedback are adaptive to the way the student chooses to construct the figure. The results of the impact of descriptive feedback have been published in [7]. The last results obtained from new field testing show that the guidance feedback has also strong impact on the kids capacity of solving harder problems. To help delivering feedbacks, a pedagogic agent has been implemented and emotional feedback should be tested soon.

Simultaneously, a Flutter source-code is being developed with the Wyatt company to allow the app to be compatible with IOS and Android platforms.

3.6 Transfer Learning for Facial Analysis with Limited and Inconsistent Annotations

Participants: Martin Dornier, Philippe-Henri Gosselin, Christian Raymond, Yann Ricquebourg, Bertrand Coüasnon.

This section sums up the work done during this thesis.

Deep learning has developed considerably in recent years. However, many existing methods are still based on supervised learning, which requires annotated data. Obtaining such data can be difficult. In this thesis, we present a methodology, based on transfer learning, for training neural networks with a low volume of annotated data. Our approach consists in augmenting a pre-trained self-supervised generative network with new layers and connections, to adapt it to a supervised image-to-image task. Unlike most methods based on transfer learning, we use the entire generative model, including the decoder, for the supervised task. Our methodology is inspired by the 3FabRec network proposed by Browatzki et al. for face alignment, which we have extended to other supervised tasks and generative networks. We have also proposed and studied different ways of augmenting the generative network for the supervised task. We applied our

methodology to two supervised tasks: face alignment and 3D face reconstruction. For the first application, our models outperformed the state-of-the-art on many datasets when the number of training data is limited. For 3D face reconstruction, we were able to improve the predictions of a self-supervised network via the addition of supervised information, but obtained with very little annotated data.

Different results of this work have been presented at peer-reviewed international conference [16] and some are currently submitted to the peer-reviewed Pattern Recognition Letters journal.

3.7 Early Recognition of gestures

Participants: William Mocaër, Eric Anquetil, Richard Kulpa.

This research project focuses on the early identification of gestures within the domain of human-machine interaction, arising from a collaboration between two specialized research teams: ShaDoc and MimeTic. The primary objective of this study is to devise a versatile methodology capable of recognizing both 2D gestures on a tablet and 3D gestures performed by the human body. The overarching goal is to achieve early recognition of these gestures, ideally before their completion, ensuring seamless interaction and responsiveness in both contexts.

The research contributions are categorized into three key aspects: gesture representation, the implementation of a deep learning-based recognition system, and the design of a decision mechanism. These components synergistically form a system capable of identifying gestures in progress at an early stage, while also exercising caution in making decisions when faced with ambiguity between multiple gestures. These approaches have proven effective in evaluations, both in the constrained setting for 2D gestures and in the untrimmed context for 2D and 3D gestures. The results and experiments conducted in this research underscore the practical applicability of these approaches in real-time interactive systems.

These work in under review in an international peer-reviewed journal.

The Ph.D. was successfully defended on December 15, 2023.

3.8 Integration of explicit knowledge with deep learning for the recognition and segmentation of children's handwriting

Participants: Simon Corbillé, Eric Anquetil, Elisa Fromont.

Our goal is to design a tool for children's handwriting recognition and segmentation in order to accurately analyze the handwriting and provide immediate orthographic feedback to the child. The contributions of this thesis are based on the hybridization of deep learning models with models using explicit expert knowledge [10].

The first contribution consists in integrating the writing dynamics of the online signal in a convolutional neural network for character recognition.

The second contribution concerns the improvement of an existing word analysis sys-

tem. This system uses a guidance mechanism based on the instruction and the words phonetically close to the instruction. It integrates the prediction of a Seq2Seq recognition model into the guidance system. The objective is to overcome the shortcomings of the guidance mechanism when the input words contain non-phonetic errors.

The third contribution proposes a new recognition and segmentation framework. It is based on the combination of a model dedicated to recognition and a model dedicated to segmentation. The system also integrates the knowledge contained in the online signal in order to improve the accuracy of the segmentation. Finally, we have developed a rejection mechanism to improve the quality of the feedback given to the child. The results of the experiments demonstrate the interest and efficiency of these contributions.

The Ph.D. was successfully defended on june 06, 2023.

3.9 Kaligo-based Intelligent Handwriting Teacher (KIHT)

Participants: Éric Anquetil, Yann Soullard, Wassim Swaileh, Florent Imbert, Romain Tavenard (LETG lab).

This work takes place within the KIHT French-German bilateral ANR project. This project is composed of two academic partners, IRISA (France) and the Karlsruhe Institut of Technology (KIT, Germany) and two industrial partners, Learn & Go (France) and Stabilo (Germany). The Stabilo company has developed a specific digital pen composed of IMU sensors, called Digipen, with which we work.
Our goal is to reconstruct the handwriting trajectory from the Digipen. The Stabilo Digipen captures time series from IMU sensors (accelerometers, gyroscope, magnetometer, force sensors) during writing, and wa aims at reconstructing the online handwriting trace from the sensors. The first step has been to create a database will serve as a benchmark to help advanced research. A part of this database is available for research purpose. [1]

Then, to reconstruct the handwriting trajectory from IMU signals, we proposed a complete pipeline (Figure 4) which consists of :

- preprocessing including an alignment strategy between input and ground-truth time series for training a neural network as well as a learning pipeline based on touching strokes,
- a neural network architecture inspired by a Temporal Convolutional Network (TCN) to cope with noisy signals coming from the inertial sensors,
- an evaluation protocol based on the Frechet distance to assess the quality of the reconstructed trajectories.

This work was presented at SIFED 2023 [17], and published in an international peer-reviewed journal [8] (with an oral presentation at ICDAR 2023 – Journal Track). This work has also been submitted to publication as part of joint articles with other partners from the KIHT project [13] and [11].

[1] Available here https://www-shadoc.irisa.fr/irisa-kiht-s-dataset/

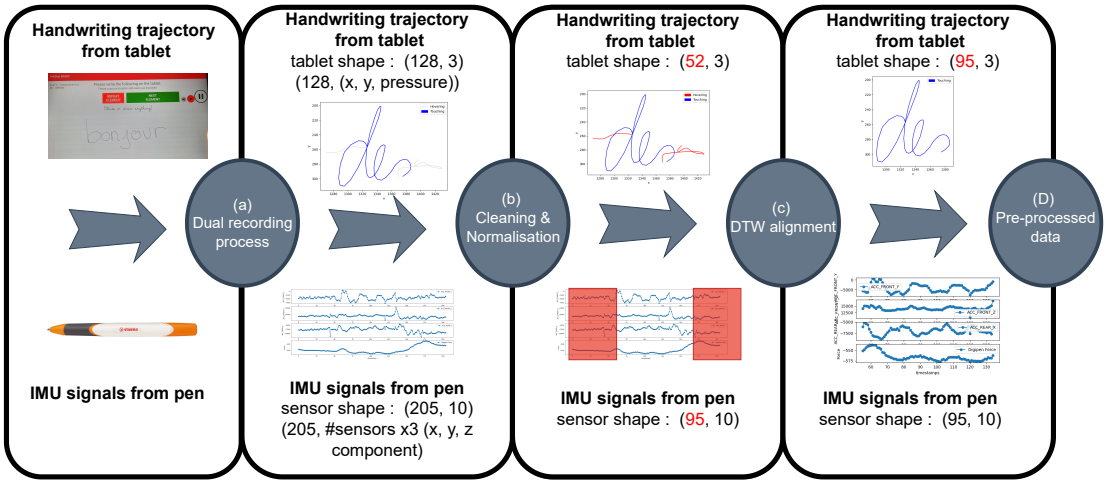

Figure 4: Our complete pipeline for synthesizing kinematic signals in order to reconstruct the handwriting trajectory

This work provides promising results, especially on touching stroke reconstruction. Reconstructing the hovering (pen-up) parts is more challenging as i) there is no ground truth trajectory at training time (the tablet does not capture any trajectory when the pen is over a threshold); ii) pen-up movements are highly variable and may be disordered; iii) the network does not perform well on data where the vertical dimension of the stylus change due to a training on touching stroke only. To improve the hovering part reconstruction, we explore the combination of 2 models: one with a restrained receptive field for touching parts and another one with an enlarged receptive field, better suited to pencil lifting parts for which we don't have the ground truth. We also explores fine-tuning on inclined data to help repositioning after hovering, indeed, inclined data permit to introduce an additional dimension during training corresponding to the height of the pen.

3.10 External language models and rejection capabilities for text recognition in difficult conditions

Participants: Florent Meyer, Yann Soullard, Bertrand Coüasnon, Guillaume Gravier, Laurent Guichard (ANTAI).

Vehicles license plate recognition is an OCR application for which the tremendous volume of contraventions recorded accounts for the need of a very high performance in the reading. Unfortunately, additionally to common image quality-related difficulties emerging from weather conditions or camera settings, the distribution of the characters on the plates is constantly evolving due to vehicles being put in and out of service which makes it harder for systems to preserve peak performance over time. A lever towards obtaining a predictor capable of adapting nearly daily is to first ignore the bias in the plates in order to better reinject a useful, up-to-date bias later on without fully retraining the model. To this end, work is being conducted on revealing where this undesired bias lies in a neural network and how it manifests, as well as on how it could be removed. ResNet-like models with diverse output layers have thus been explored since the end of 2023.

3.11 Projet AIR : Intuinote

Participants: Éric Anquetil, Nathalie Girard, Bruno Hortollary.

IntuiNote is a new digital active learning environment for synchronous teaching (face-to-face and distance learning). Its aim is to optimize the possibilities for interaction between teacher and learners. In particular, it is based on handwritten note-taking and graphical MCQs developed on the fly on a on a touch tablet/stylus.

This work is part of the AIR project (ANR-21-DMES-0001, section 5.2.5) set up by Rennes University. It is based Kassis/IntuiNote digital learning environment, which is the result of the e-FRAN "Actif" project and the Labex: CominLabs - e-FIL.

IntuiNote has been updated and deployed on a server for testing purposes. Intuinote includes an application for Windows tablets, a server and a web client enabling cross-platform use. Experiments are currently underway to determine the impact of Intuinote on student learning. These experiments are being carried out in collaboration with the LP3C Laboratory of the University of Rennes 2.

4 Software development

4.1 IntuInaxe App

Participants: Eric Anquetil, Omar Krichen, Bruno Hortollary.

We have launched a new research and transfer contract with Inaxe company in 2023. The aim is to design a new pen-based application on a Windows tablet based on AI Technologies of our research Team (DALI, Evolve...) for freehand transfer (gesture recognition) of asbestos and lead surveys on building plans.

This transfer work led in December 2023 to an APP registration and a licence with the company.

4.2 Automatic edition of Journals on 18th-century soldiers

Participants: Ivan Leplumey, Yann Ricquebourg.

The "Revues sur les soldats du XVIII^{e} siècle" (Journals on 18th-century soldiers) project involves a direct collaboration with the "Mémoire des Hommes" website[2], the cultural portal of the French Ministry of the Armed Forces. We use manual annotations of old documents to create several types of digital journals able to evolve: the first of a geographical type for associations and departmental archives, the second of a regimental type for the "Mémoire des Hommes" website or for the ten annotators taking part in the project (see Figure 5). These reviews, produced in LaTeX, mainly contain ordered lists of soldiers linked to their original image on the web by hypertext links. Regimental histories, statistics and indexes complete the content of these journals. To date, the project has produced 70 journals, 38 of them geographical, totaling 19,000 pages.

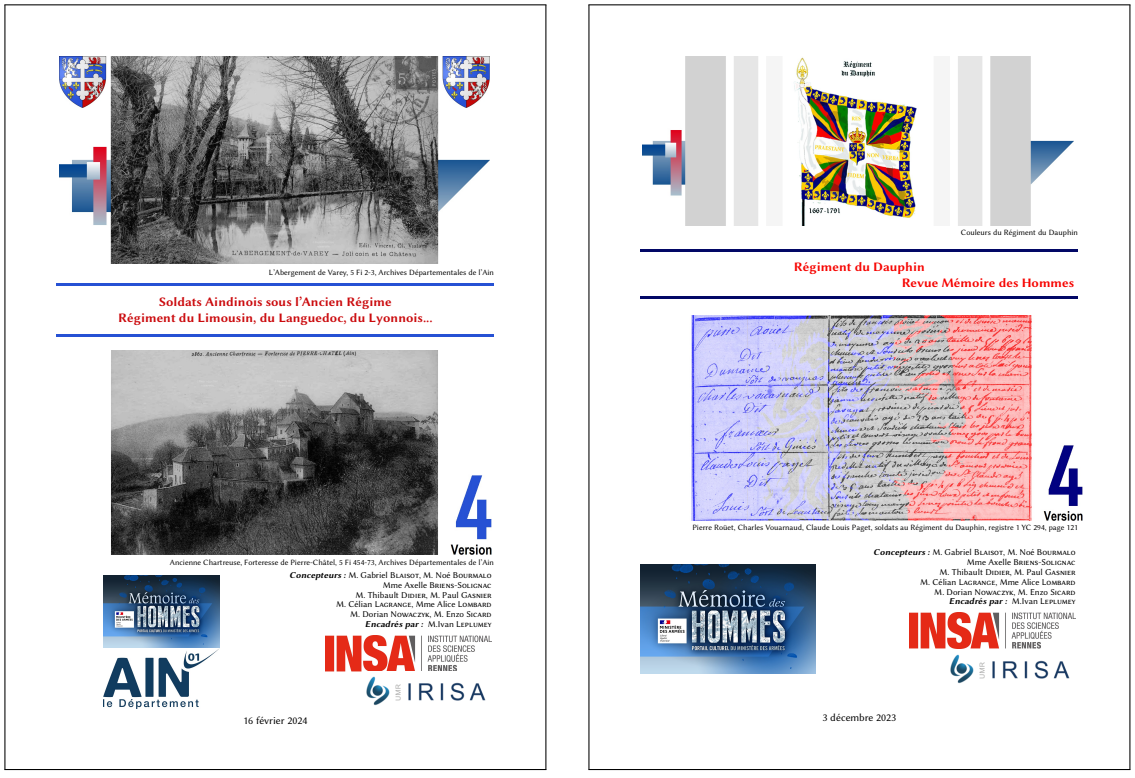

Figure 5: (left) Cover of the Ain department journal produced with the Ain departmental archives, (right) Cover of the Dauphin's regiment journal

[2] https://www.memoiredeshommes.sga.defense.gouv.fr

5 Contracts and collaborations

5.1 International Initiatives

5.1.1 French-German bilateral ANR project in artificial intelligence (KIHT - Kaligo-based Intelligent Handwriting Teacher)

Participant: Éric Anquetil, Yann Soullard, Wassim Swaileh, Florent Imbert, Romain Tavenard (LETG lab, IRISA).

- Project type: French-German bilateral ANR project KIHT - Kaligo-based Intelligent Handwriting Teacher
- Dates: 2021–2024
- Role : We are the project leader of the french part.
- PI institution: IRISA (French part - ANR) and Stabilo (German Part - BMBF)
- Other partners: STABILO International GmbH, Karlsruher Institut für Technologie Institut für Technik der Informations¬verarbeitung, LearnAndGo company

In this project, we will design a new intelligent device to help learning handwriting in classrooms. The originality of the project consists in designing a new handwriting capture device developed by the company STABILO: a digital pen equipped with kinematic sensors (inertia measurement units (IMUs)) that allows writing on any surface (screen and paper).

The Stabilo company, supported by the German laboratory KIT, has the task of designing the hardware of the digital pen as well as embedding the AI algorithms developed. On our side, we are working, through a thesis and a post-doc, on the design of an original and powerful deep neural network architecture to automatically synthesise the online handwriting from the kinematic signals produced by the digital pen sensors.

5.2 National Initiatives

5.2.1 ANR CollabScore: Shared spaces for digital music scores

Participant: Bertrand Coüasnon, Aurélie Lemaitre, Yann Soullard, Ali Yesilkanat, Hugo Hazard, Jean Camillerapp, Nathalie Girard, Denis Coquenet.

- Project type: ANR CollabScore
- PI institution: CNAM
- Other partners: Cnam, INSA, BnF, Antescofo, IReMus, Fondation Royaumont
- 48 months (2020–2025)
- Contract: INSA

The project is dedicated to the collaborative digitization of music scores currently available only as images in museum collections. It will combine OMR (Optical Music Recognition) and a crowdsourcing correction phase of remaining recognition errors. A reconciliation step of the different versions will be automated with specifically developed software, to obtain a reference score. This fulcrum notation will then be used in conjunction with several sources, to enhance the user experience. For instance, listening could be assisted by the synchronized scrolling of the score, and augmented with musicological annotations. The project aims at solving some scientific challenge, first by guiding and controlling an OMR process with musical knowledge, then by elaborating an automated crowdsourcing process.

5.2.2 Directory of Musical Writings of the Music Department of the BnF

Participant: Bertrand Coüasnon, Aurélie Lemaitre.

- Partners: Université de La Rochelle, INSA, BnF
- PI institution: Université de La Rochelle
- 48 months (2020-2024)
- Contract: INSA

Collaboration project on the constitution of a directory of musical writings of the collections of the Music Department of the BnF. Taking into account both autograph manuscripts and manuscripts by identified or anonymous copyists, the project will study the indexing of scripts on graphic characteristics.

5.2.3 ANR SKETCH : Sketches analysis and interpretation for the design of an intelligent tutorial system for medical studies

Participant: Eric Anquetil, Nathalie Girard, Islam Barchouch, Omar Krichen.

- Role : LP3C is the project leader, we are scientific leader of the AI part.
- Partner: *LP3C*, *IFPS*, *IFPEK*, *INSA*
- 42 months (2022-2026).
- Contract: INSA

Several recent studies have demonstrated that educational activities based on drawing can have positive effects on the learning of scientific concepts. The advent of innovative devices such as pen-based tablets means that new types of scaffolding involving artificial intelligence can now be designed and assessed. This opens up interesting avenues of research, as these devices make it possible to provide learners not only with

support that can be parameterized by the instructor, but also with automatic and personalized realtime feedback during the drawing task.

The twofold aim of the SKETCH project is to 1) collaboratively design an intelligent tutoring system (ITS) that can analyze learners' actions in real time during the freehand production of a complex scientific drawing on a tablet, and 2) assess and optimize the effects of this system and the feedback it provides on learning. This project will be carried out jointly by two research teams in Rennes (France): the Psychology, Cognition, Behavior & Communication Laboratory (LP3C), and the ShaDoc (IntuiDoc) team at the Computer Science Laboratory (IRISA). It will focus on drawing activities intended to enhance learning about anatomy. Two of the partners in the project are paramedical colleges: IFPEK and IFPS. This will allow instructors and students to be involved in the project.

5.2.4 ANR(e-Fran) TRIANGLE : Working with Intelligent Feedback from a Digital Geometry Application for Student Engagement

Participant: Eric Anquetil, Nathalie Girard, Sarah Bucquet, Erell Choulette, Omar Krichen.

- Role: LP3C is the project leader, we are scientific leader of the AI part.
- Partner: *LP3C*, *Rennes and Poitiers academies*, *Rennes and Niort INSPE*, *INSA*
- 24 months (2022-2025).
- Contract: INSA

The objective of the TRIANGLE project is to consolidate the IntuiGéo application (intelligent tutorial system for geometry learning assistance on a tablet with a pen) by improving the impact of correction and guidance feedbacks, notably by adding a virtual pedagogical agent. We will also study the effects of this type of assistance on students' performance and engagement. Finally, in terms of dissemination, evaluation studies will be conducted in two academies. The deployment of a free multi-platform version in schools is planned at the end of the project. The consortium is made up of a research team in computer science (ShaDoc (IntuiDoc)/IRISA, Rennes), a research team in psychology and ergonomics of learning (LP3C, Rennes), two INSPEs in close collaboration with the Academic Delegations for Digital Education (DANe) in two academies (Rennes and Poitiers).

5.2.5 AMI "Digital demonstrators in higher education" / AIR project- Increasing Interaction in Rennes

Participant: Eric Anquetil, Nathalie Girard, Bruno Hortollary.

- Role : Univ Rennes is the project leader, we are member of the consortium

- Partners: Univ. Rennes, INSA, Univ. Rennes 2
- 24 months (2022-2025).
- Contract: INSA

In this project we will consolidate and experiment in collaboration with the LP3C (UR2) and the University of Rennes, the KASSIS software suite which is a digital device we designed for pen based tablets to support synchronous active learning in class and remotely.

5.3 Bilateral industry grants

5.3.1 Research contract Inaxe company

Participant: Eric Anquetil, Omar Krichen, Bruno Hortollary.

- Partners: *Inaxe company*
- 2023-2024
- Contract: INSA Rennes

Following on from a 1st transfer with the company Inaxe in 2018, we have launched a new research and transfer contract with the same company in 2023. The aim is to design a new pen-based application on a Windows tablet based on AI Technologies of our research Team (DALI, Evolve...) for freehand transfer (gesture recognition) of asbestos and lead surveys on building plans. This transfer work led in December 2023 to an APP registration and a licence with the company. The IntuiNaxe application will be deployed in 2023-2024.

5.3.2 Research contract Interdigital company (CIFRE)

Participant: Christian Raymond, Bertrand Coüasnon, Yann Ricquebourg.

- Partners: *Interdigital company*
- 2020-2023
- Contract: INSA

Shadoc team started to work with Interdigital company on latent representations in deep learning. This collaboration is based on the CIFRE grant for the PhD of Martin Dornier.

Current activities are described in section 3.6.

5.3.3 Research contract AriadNext company (CIFRE)

Participant: Aurélie Lemaitre, Bertrand Coüasnon, Yann Soullard.

- Partners: *AriadNext company*
- Since 2021
- Contract: INSA

Shadoc team started to work with AriadNext company in the field of document recognition applied to identity documents. This collaboration is based on a CIFRE grant for the PhD of Timothée Neitthoffer.

Current activities are described in section 3.3.

5.3.4 Research contract ANTAI (CIFRE)

Participant: Yann Soullard, Bertrand Coüasnon, Guillaume Gravier.

- Partners: *ANTAI*
- Since 2023
- Contract: INSA

Shadoc team started to work with ANTAI on recognition with rejection capabilities and external language models with application on licence plate recognition. This collaboration is based on a CIFRE grant for the PhD of Florent Meyer.

Current activities are described in section 3.10.

6 Dissemination

6.1 Promoting scientific activities

6.1.1 Scientific Events Organization

Organization of International Workshop

- ADAPDA 2023 (USA): Eric Anquetil Co-organized the international workshop for ICDAR2023, "Automatically Domain-Adapted and Personalized Document Analysis (ADAPDA)" with Prof. Rita Cucchiara, prof. Eric Anquetil, and Christopher Kermorvant.

General Chair, Scientific Chair

- A. Lemaitre organized the Arts, Culture and Heritage cross-disciplinary seminar, at IRISA, on January 19th.
- A. Lemaitre organized the seminar "1 Artist / 1 Scientist" at IRISA, on June 27th.

6.1.2 Scientific Events Selection

Chair of Conference Program Committees

- N. Girard was program co-chair of the 15th IAPR International Workshop on Graphics Recognition (GREC 2023), in August 2023. `https://grec2023.univ-lr.fr/`

Member of Conference Program Committees

- E. Anquetil and N. Girard were Program Committee members of 21st International Conference of the International Graphonomics Society on Graphonomics in Human Body Movement, in October 2023. `https://graphonomics.net/igs2023/`
- E. Anquetil and A. Lemaitre are members of the program committee of the International Conference on Document Analysis and Recognition (ICDAR 2023)
- B. Coüasnon is Senior member of the program committee of the International Conference on Document Analysis and Recognition (ICDAR 2023).
- E. Anquetil and B. Coüasnon is member of the program committee of the 15th IAPR International Workshop on Graphics Recognition (GREC 2023).
- B. Coüasnon is member of the program committee of the 7th International Workshop on Historical Document Imaging and Processing (HIP 2023).

Reviewer

- N. Girard and Y. Soullard are reviewers for the International Conference on Document Analysis and Recognition (ICDAR) in 2023,
- N. Girard is reviewer for IGS 2023 : Conference of the International Graphonomics Society.

6.1.3 Journal

Reviewer - Reviewing Activities

- E. Anquetil is reviewer fo IEEE Transactions on Human-Machine Systems (IEEE THMS)

- N. Girard, A. Lemaitre and Y. Soullard are reviewers for the International Journal on Document Analysis and Recognition (IJDAR) in 2023.
- A. Lemaitre is reviewer for a book publication in PUR (Presses Universitaires de Rennes) in 2023.

6.1.4 Invited Talks

- E. Anquetil presented « En quoi l'Intelligence Artificielle peut permettre un apprentissage personnalisé et individualisé ? » EdTech Grand Ouest, 03/2023.
- B. Coüasnon and Y. Soullard presented "OCR : de l'historique à l'état de l'art" at Valconum Seminar, LIPADE, Université Paris Cité, 2023/03/23.
- D. Coquenet presented "Attention is all you need to read" at Journée Attention de l'axe DAC/Image de Normastic, INSA Rouen, 2023/10/19.
- D. Coquenet presented "From Text Recognition to Document Understanding" at NER for Historical Documents seminar, Sorbonne Université, 2023/11/16.

6.1.5 Leadership within the Scientific Community

6.1.6 Scientific Expertise

- E. Anquetil was a member of a recruitment committee of professor (COS PR27): Université Paris Cité - 2023.
- A. Lemaitre was a member of a recruitment committee of assistant professor: in May 2023 (IUT La Rochelle).
- B. Coüasnon was a scientific expert in 2023 on a project for Innoviris, Brussels.

6.1.7 Research Administration

- Shadoc members are members of the AFRIF (Association Française pour la Reconnaissance et l'Interprétation des Formes) and IAPR (International Association for Pattern Recognition) associations.
- E. Anquetil is a member of the educational committee of the "DIGISPORT" University Research School (EUR).
- E. Anquetil is project manager for "Innovation and Entrepreneurship" at INSA Rennes.
- E. Anquetil is the manager of the incubator for innovative projects at INSA Rennes.
- E. Anquetil is the co-manager of the inter-institutional student incubator for innovative projects from 10 higher education institutions in Rennes: Station Rennes Innovation.
- E. Anquetil is an elected member of the administration council of INSA Rennes.
- E. Anquetil is a member of the administration council of INSA Group Foundation.
- E. Anquetil is a member of the « Science-Society committee » of TISSAGE Project.
- B. Coüasnon is an elected member of the scientific council of INSA Rennes.
- B. Coüasnon is an elected member of the laboratory council of the INSA component of IRISA.

- B. Coüasnon is member of the Gender Equality Commission of IRISA.
- B. Coüasnon is member of the board of Valconum (Centre Européen de Valorisation Numérique).
- B. Coüasnon is member of the laboratory council of IRISA.
- N. Girard, A. Lemaitre and Y. Soullard are members of the executive committee of the society GRCE : " Groupe de Recherche en Communication Écrite ".
- N. Girard is an elected member of the administration council of UFR ISTIC, Univ. Rennes 1.
- A. Lemaitre is responsible for the Arts, Culture and Heritage transversal theme at IRISA.
- Y. Ricquebourg is an elected member of the scientific council of INSA Rennes.

6.1.8 Awards

- IAPR Best Poster Award, 17th International Conference on Document Analysis and Recognition, Simon Corbillé, Eric Anquetil, Elisa Fromont, August 2023.
- Innovation Award, Les rencontres AGIR, Gendarmerie Nationale and Réseau SATT, DMOS-PI, Bertrand Coüasnon, Aurélie Lemaitre, November 2023.

6.2 Teaching, supervision

6.2.1 Teaching

The team is mainly made up of teachers who are very implied in activities of teaching. But a majority of lectures are not attached to this research topic, so they are not mentioned here.

- E. Anquetil is program manager of the MASTER OF SCIENCE *"Innovation and Entrepreunership"* of INSA and Rennes School of Business (RSB).
- E. Anquetil, N. Girard and D. Coquenet give lectures at *Research in Computer Science (SIF)* MASTER of University of Rennes, University of Southern Brittany, ENS Rennes, INSA Rennes and CentraleSupélec.
- E. Anquetil is in charge of the module "Analysis, Interpretation and Recognition of 2D (touch) and 3D Gestures for New Man-Machine Interactions" (AIR) of the *Research in Computer Science (SIF)* MASTER of University of Rennes, University of Southern Brittany, ENS Rennes, INSA Rennes and CentraleSupélec.
- E. Anquetil is in charge of the module "Motion Analysis and Gesture Recognition (2D / 3D)" (AMRG) of the COMPUTER SCIENCE DEPT. of INSA Rennes.
- B. Coüasnon is co-Head with A. Termier of the *Research in Computer Science (SIF)* MASTER of University of Rennes 1, University of Southern Brittany, ENS Rennes, INSA Rennes and CentraleSupélec (https://master.irisa.fr).
- B. Coüasnon is in charge (with M. Babel) of the module "Image & Video Analysis" (TIV) of the COMPUTER SCIENCE DEPT. *(Medias & Interactions section)* of INSA Rennes.
- N. Girard was invited for two courses at MASTER AND MASTER-RESEARCH "Découverte de la recherche" at La Rochelle University on : "IA for e-education", La Rochelle and Niort, France.

- Y. Ricquebourg and E. Anquetil are in charge of the module "Recognition and Interpretation of Images & Videos" (RIV) of the Computer Science Dept. *(Medias & Interactions section)* of INSA Rennes.
- Y. Soullard is in charge of the part "Text Mining and Deep Learning" of the module "Introduction to the Text Mining" at Master MAS *(Applied Mathematics, Statistics (Data Science))* of Rennes 2 University.
- Y. Soullard is in charge of the part "Recurrent Networks and Time Series Analysis" of the module "Deep Learning" at Master TELENVI *(Remote Sensing-Environment)* of Rennes 2 University and Agrocampus Ouest.
- Y. Soullard is in charge of the part "Deep Learning for Sequential Analysis" of the module "Deep Learning" of the DIGISPORT Master *(Digital and Sport Sciences)* of the University Research School (EUR) DIGISPORT.
- Y. Soullard is in charge of the module "Data Mining & Clustering" of the DIGISPORT Master *(Digital and Sport Sciences)* of the University Research School (EUR) DIGISPORT.

6.2.2 Supervision

- K. Barrere, Lightweight Transformer-based Architectures for Historical Handwritten Text Recognition, B. Coüasnon, A. Lemaitre, Y. Soullard, INSA Rennes, PhD defended December 2023 [1].
- S. Corbillé, Hybridization of "Transparent" and "Deep Learning" AI approaches for automated handwriting analysis of children in the context of education, E. Anquetil, E. Fromont, Univ. Rennes 1, PhD defended June 2023 [2].
- M. Dornier, Transfer Learning for Facial Analysis with Limited and Inconsistent Annotations, B. Coüasnon, P.H. Gosselin, C. Raymond, Y. Ricquebourg, INSA Rennes, defended December 2023 [3].
- A. Lods, On-line analysis of handwritten arithmetic operation on digital tablet: Design of an innovative educational solution to improve learning arithmetic calculations in elementary school, E. Anquetil, S. Macé, INSA Rennes, PhD defended September 2023 [4].
- W. Mocaër, Spatio-Temporal Convolutional Neural Network for early action detection and analysis, E. Anquetil, R. Kulpa, INSA Rennes, PhD defended December 2023 [5].
- PhD in progress: I. Barchouch, Intelligent tutorial system for sketch-based learning (SKETCH), E. Anquetil, N. Girard, started October 2022.
- PhD in progress: F. Imbert, Design of a deep neural network architecture dedicated to the synthesis of handwriting from kinematic sensors of a sensors of a digital pen, E. Anquetil, Y. Soullard, R. Tavenard, INSA Rennes, started October 2021.
- PhD in progress: F. Meyer, External language models and rejection capabilities for text recognition in difficult conditions, B. Coüasnon, G. Gravier, Y. Soullard, L. Guichard (ANTAI), INSA Rennes, started June 2023.
- PhD in progress: T. Neitthoffer, Joint analysis of handwriting localization and recognition in structured documents, B. Coüasnon, A. Lemaitre, Y. Soullard, A. M. Awal (AriadNext), INSA Rennes, started May 2021.

6.2.3 Juries

- E. Anquetil was reviewer in the thesis committee of Elmokhtar MOHAMED MOUSSA's PhD, Offline to online handwriting conversion with deep neural networks, Nantes University, January 2024.
- A. Lemaitre was reviewer in the thesis committee of Korlan Rysbayeva's PhD, Deep metric learning and classification of hierarchical and multimodal data: an application to soil remediation reports, Bordeaux University, July 2023.
- A. Lemaitre was reviewer in the thesis committee of Thibault Douzon's PhD, Language Models for Document Understanding, INSA Lyon, October 2023.
- A. Lemaitre was member of the thesis committee of Tien Nam Nguyen's PhD, Reconnaissance et Indexation de caractères dans les documents CHAM, La Rochelle Université, July 2023.
- E. Anquetil is member of mid-term evaluation committee of the PhD candidate: Y. XIE (Université de Nantes, LS2N/IPI).
- B. Coüasnon is member of mid-term evaluation committee of the PhD candidate: Thomas Constum (Université de Rouen-Normandie, LITIS).
- N. Girard is member of mid-term evaluation committee of the PhD candidate: T. Legay (Insa Rennes, IETR).
- A. Lemaitre is member of mid-term evaluation committee of the PhD candidate Ibrahim Souleiman (La Rochelle Université).
- Y. Ricquebourg is member of mid-term evaluation committee of the PhD candidate: Tsiry Mayet (Insa Rouen, LITIS).

6.2.4 Patent and Deposit of digital creations (APP)

- E. Anquetil, O. Krichen, B. Hortollary deposited (APP) the IntuInaxe App in 2023/2024 :IntuiNaxe - IntuiNaxe IDDN.FR.001.030020.000.S.P.2024.000.10000.

7 Bibliography

Major publications by the team in recent years

[R1] S. Adam, J. Annaert, F. Buelens, B. Coüasnon, B. Cule, A. de Vicq, C. Guerry, P.-C. Hautcoeur, T. Paquet, A. R. Camacho, I. Le Floch, A. Lemaitre, P. Karapanagiotis, J. Poukens, A. Riva, "Data extraction and matching The EurHisFirm experience", *in : Methodological Advances in the Extraction and Analysis of Historical Data, Methodological Advances in the Extraction and Analysis of Historical Data*, Kellogg School of Management - Northwestern University, Chicago/Virtual, United States, December 2021, `https://hal.archives-ouvertes.fr/hal-03828381`.

[R2] K. Barrere, Y. Soullard, A. Lemaitre, B. Coüasnon, "Transformers for Historical Handwritten Text Recognition", *in : 16th International Conference on Document Analysis and Recognition (ICDAR 2021) Doctoral Consortium*, 2021.

[R3] K. Barrere, Y. Soullard, A. Lemaitre, B. Coüasnon, "A Light Transformer-Based Architecture for Handwritten Text Recognition", *in : International Workshop on Document Analysis Systems*, Springer, p. 275–290, 2022.

[R4] K.-Y. Choi, B. Couasnon, Y. Ricquebourg, R. Zanibbi, "CNN-Based Accidental Detection in Dense Printed Piano Scores", *in : 15th International Conference on Document Analysis and Recognition*, Sydney, Australia, September 2019, https://hal.archives-ouvertes.fr/hal-02430041.

[R5] M. Dornier, P.-H. Gosselin, C. Raymond, Y. Ricquebourg, B. Coüasnon, "SCAF: Skip-Connections in Auto-encoder for Face Alignment with Few Annotated Data", *in : ICIAP 2022 - International Conference on Image Analysis and Processing*, *Lecture Notes in Computer Science*, *13231*, Springer International Publishing, p. 425–437, Lecce, Italy, May 2022, https://hal.archives-ouvertes.fr/hal-03687091.

[R6] C. Guerry, *Big-data historique : modélisation de stratégies d'analyse de collections de documents*, Theses, INSA de Rennes, December 2022.

[R7] O. Krichen, E. Anquetil, N. Girard, "IntuiGeo: Interactive tutor for online geometry problems resolution on pen-based tablets", *in : European Conference on Artificial Intelligence (ECAI) 2020*, p. 1842 – 1849, Santiago de compostela, Spain, August 2020, https://hal.archives-ouvertes.fr/hal-02544384.

[R8] O. Krichen, S. Corbille, E. Anquetil, N. Girard, E. Fromont, P. Nerdeux, "Combination of explicit segmentation with Seq2Seq recognition for fine analysis of children handwriting", *International Journal on Document Analysis and Recognition*, November 2022, https://hal.archives-ouvertes.fr/hal-03845144.

[R9] O. Krichen, S. Corbillé, E. Anquetil, N. Girard, P. Nerdeux, "Online analysis of children handwritten words in dictation context", *in : 14th International Workshop on Graphics Recognition*, Lausanne, Switzerland, September 2021, https://hal.science/hal-03448357.

[R10] A. Lemaitre, J. Camillerapp, C. Carton, B. Coüasnon, "A combined strategy of analysis for the localization of heterogeneous form fields in ancient pre-printed records", *International Journal on Document Analysis and Recognition 21(4)*, 269-282, July 2018, https://hal.inria.fr/hal-01858192.

[R11] C. Leroy, E. Anquetil, N. Girard, "Drift anticipation with forgetting to improve evolving fuzzy system", *in : 25th International Conference on Pattern Recognition (ICPR2020)*, Milan, Italy, January 2021, https://hal.archives-ouvertes.fr/hal-02974253.

[R12] N. Michinov, E. Anquetil, E. Michinov, "Guiding the use of collective feedback displayed on heatmaps to reduce group conformity and improve learning in Peer Instruction", *Journal of Computer Assisted Learning*, June 2020, https://hal.univ-rennes2.fr/hal-02875166.

[R13] W. Mocaër, E. Anquetil, R. Kulpa, "Early Recognition of Untrimmed Handwritten Gestures with Spatio-Temporal 3D CNN", *in : ICPR 2022-International Conference on Pattern Recognition*, 2022.

[R14] R. Plamondon, G. Pirlo, E. Anquetil, C. Rémi, H.-L. Teulings, M. Nakagawa, "Personal Digital Bodyguards for e-Security, e-Learning and e-Health:A Prospective Survey", *Pattern Recognition 81*, September 2018, p. 633–659, https://hal.science/hal-01767055.

[R15] S. Tarride, A. Lemaitre, B. Coüasnon, S. Tardivel, "Combination of deep neural networks and logical rules for record segmentation in historical handwritten registers using few examples", *International Journal on Document Analysis and Recognition*, January 2021, https://hal.archives-ouvertes.fr/hal-03160212.

[R16] C. Truong, L. Oudre, N. Vayatis, "Selective review of offline change point detection methods.", *in : Signal Processing, 167, 107299*, IEEE, p. 770–778, 2020.

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[1] K. Barrere, *Lightweight Transformer-based Architectures for Historical Handwritten Text Recognition*, Theses, INSA Rennes, December 2023, https://hal.science/tel-04385383.

[2] S. Corbille, *Intégration de connaissances explicites à l'apprentissage profond pour la reconnaissance et la segmentation d'écriture manuscrite d'enfants* , Theses, Institut national des sciences appliquées de Rennes, July 2023.

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