FormTwin: A Framework for Pen-based Data Collection

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ABSTRACT

Paper and digital forms are widely used to collect user information across multiple domains, such as research, healthcare, and education. However, both types still lack application and follow-up interpretation: Paper forms need to be digitised meticulously to be analyzed or shared with team members efficiently; in comparison, digital forms cannot convey handwriting and might require technical literacy. We present the FormTwin data collection tool—an alternative to online forms, which allows for the efficient reuse of existent paper forms while providing the convenience of digital forms. FormTwin can digitise a wide range of forms with the integrated form annotation application. Then, it combines two input channels: A stylus on a tablet and a digital smart pen on plain paper, which duplicates the input on a mobile application in real-time. We aim to improve the efficiency and accessibility of data collection for practitioners with a modular system that combines both the digital accessibility of digital forms with keeping the needed technical literacy low and retaining the quality of hand-drawn sketches.

CCS CONCEPTS

• **Human-centered computing → Systems and tools for interaction design**; *Ubiquitous and mobile devices*; *Interaction techniques*; **Interaction devices**; **Human computer interaction (HCI)**.

KEYWORDS

Digital Pen, Digital Forms, Data Collection Methods, Research Tools, Intelligent User Interfaces

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1 INTRODUCTION

Forms are widely used to collect user information across multiple domains, such as research, healthcare, and education. Researchers in user studies collect user data via forms either in paper or digital formats. Paper forms require digitisation afterwards, either manually or with optical character recognition (OCR) techniques, which can be time-consuming, prone to errors, and significantly delay data processing. However, digital forms with electronic data capture methods address this problem, which can result in substantial savings in time and budget [4, 5, 8, 15]. In addition, digital forms can be easily created and updated, providing end-users with an interactive user interface (UI) and allowing integration with knowledge-based and data-processing systems. Further, digital forms can be widely presented on desktop or handheld devices such as tablets and smartphones. This interface increases portability, ease of use, and resemblance to traditional paper forms [3]. However, digital forms may cause usability challenges for people with low technical literacy, such as elderly people, which can impact the collected data [6, 16]. This can lead to higher productivity using paper-based forms in certain target groups [6, 16]. Additionally, digital sketches and drawings might show lower input quality and accuracy compared to paper-based formats [2].

Digital pens offer a solution to overcome the usability challenges of digital forms. They combine the benefits of digital forms regarding data collection with the ability to convey the information of traditional pen-based forms. In addition, digital pens can collect coordinates and timestamps, which can be used to compute additional features, like time spent on different sections of the form. For example, Barz et al. [1] showed that signals of digital pens could be predictive of cognitive states, cognitive load, and emotions in educational settings. Further, digital pens can digitise neuropsychological tests, which have been traditionally performed using pen and paper with manual evaluation by physicians [13].

In this paper, we introduce FormTwin, a tool designed to bridge the gap between traditional paper forms that need to be digitised, while preserving input characteristics, and digital techniques that facilitate the analysis of collected data, but might not be suitable for specific target groups. With FormTwin, the data collection can be easily modified to cater to different task characteristics and user groups. This allows the personalization and adaption of forms to support a wide range of user studies and use cases. FormTwin consists of three components: The *Form Annotation Application*, the *Mobile Application*, and the *Backend*. First, the user can use the *Form Annotation Application* to annotate fields and create a digital version of their pre-existing forms. The form can then be loaded into the *Mobile Application* and filled out in two ways: Either directly in the mobile application as a digital form using a stylus, or as a printed paper-based form using a digital smart pen that is connected to the mobile application. With the two channels to fill the form, FormTwin supports both digitisation and digitalisation: Users can fill out a paper-based form using a digital pen, with the handwriting results immediately recognised, stored, and processed for digitisation; alternatively, users can complete the digital form on the mobile device, which represents a digitalized process for form filling. The system also supports the transformation of written data into multiple data types and allows free-form drawings, which are particularly useful for annotation tasks and sketch acquisition. The upcoming sections start by describing the different elements of our system and provide examples of the application and evaluation of FormTwin.

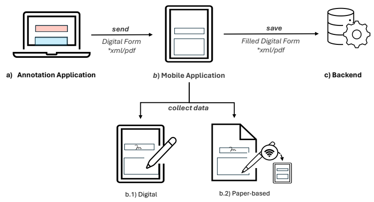
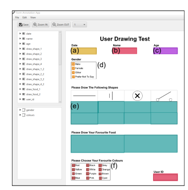


Figure 1: Overview of the architecture of FormTwin- a data collection framework.



(a) Form Annotation Application

(b) Mobile Application

Figure 2: An example of an annotated form in the *Form Annotation Application* and in the *Mobile Applications* of FormTwin.

2 SYSTEM DESIGN

FormTwin is an application that digitises forms and supports filling them out in digital or paper-based formats. It consists of three components: The *Form Annotation Application*, *Mobile Application*, and the *Backend*. A workflow of how FormTwin works is shown in fig. 1. First, (a) the *Form Annotation Application* allows practitioners to load existing digital or scanned paper forms and annotate them with different pre-defined input types; this creates a digitised twin, which can be filled in step (b). The annotated digital form is then exported as a PDF for printing and as an XML for the mobile application. (b) The *Mobile Application* of FormTwin allows users to fill out forms using two input channels: First, (b.1) users can load the digitised form into the mobile application and fill it out directly using a stylus. Any Android device that supports the use of a stylus can be used, ranging from smartphones to tablets. Second, (b.2) users can print the digitised form on regular paper and filled out by connecting a Neo Smartpen[1]. The hand-written content is mapped to the digital version on the mobile application in real time. Both input channels can be used simultaneously, which enables dynamic switching from digital to paper-based input depending on the task characteristics. Lastly, (c) the resulting form can be stored either on the mobile device as a PDF or an XML, or sent to the *Backend* to be stored and processed there.

The flexibility of having one combined solution that supports both digitisation and digitalisation promises several advantages: First, practitioners can tailor their use of digital or paper-based forms based on the availability of mobile devices or smart pens. That way, FormTwin can be cost-effective and accessible. Further, the paper-based format accommodates technical literacy and simulates the original paper-based scenario. In addition, practitioners can monitor users' progress during studies on the mobile application via the digital twin without disturbing the experimental setting. At the same time, the digital form on the mobile device facilitates the storing and sharing of information among team members and supports the analysis of collected data without a prior need for digitisation. The following sub-sections give a closer insight into the three presented components of FormTwin.

2.1 Form Annotation Application

The *Form Annotation Application* enables practitioners to create an annotated version of a form after scanning or uploading it. Our system requires the annotation of input fields to properly map a user's input to the form elements. This mapping is created by the user using the FormTwin desktop application, which is developed with the JavaFX framework[2]. The application allows for the importation of a form in PDF, PNG, or JPEG formats and the manual annotation of it with labelled bounding boxes. Each annotation is represented as a rectangular area with an ID, field name, and field type. While the ID is generated automatically when adding a bounding box, the user needs to specify the field name and type. The fields can store different data types, as shown in fig. 2a: (a) date entries, (b) textual information, (c) numerical values, (d) categorical selections via radio buttons, (e) free-form drawings, and (f) multiple choices via checkboxes. Different fields can be combined into groups to accommodate different topics and sections of a form. After annotation, the form is stored as a scheme in an XML format and a PDF file for printing. The XML file contains the digital representation of a form, i.e., the list of field annotations and the Base64 encoding of the form images. This XML file can be uploaded into the *Form Annotation Application* again for further editing.

[1]https://neosmartpen.com/product-n2/

[2]https://openjfx.io/

2.2 Mobile Application

The annotated form is then uploaded to the *Mobile Application* and can be filled out using two different methods: Either *Digital* directly on the mobile device through the mobile application using a stylus, or *Paper-based* on a printed form that is using a digital pen connected to the mobile device. Both channels can be used simultaneously, allowing practitioners to mix channels based on form characteristics or to monitor the process.

2.2.1 Digital. After annotating a form, the generated XML scheme can be loaded into the *Mobile Application*, shown in fig. 2b. The application renders the annotated form on a tablet touchscreen. As the user enters the data, the application instantly recognises stylus or touch gestures, and the user's handwriting is mapped to certain form fields. Touch gestures, such as pinch or drag, are used to zoom or navigate through the form. Stylus input is transformed into strokes, which are often grouped together based on when they were generated. Additionally, they are assigned to the corresponding form element based on their location on the form scheme. After this, the input of the strokes is categorized as a gesture, drawing, or handwritten text. These input types are then further processed. First, depending on the specific field type, handwriting is transformed into entities, such as text, numbers, dates, or chosen options. Further, for free-form areas, the raw pen data are recorded, i.e., the relative screen coordinates, pen pressure, and time stamps. The handwriting recognition and gesture analysis is performed with the help of the commercial state-of-the-art engine MyScript[3], which supports handwriting in several languages and various geometric shapes. Throughout filling out the digital form, users are provided with immediate feedback about the recognition results through Android toast messages, i.e. small pop-up messages that provide users with feedback without interrupting their interaction. Additionally, the FormTwin *Mobile Application* supports editing and deleting incorrect input through crossing-out and hatching gestures.

2.2.2 Paper-based. Our system supports data collection using a digital smart pen on a paper-based form. This requires printing the generated PDF form on any regular paper and loading the XML scheme into the *Mobile Application*. Paper-based forms with pen input simulate the original experience of filling out a form and can convey hand-writing and sketching better than in digital forms [13]. For that, FormTwin leverages the Neo Smartpen technology[4], which provides a digital pen that resembles traditional ballpoint pens and digitises writing on plain paper. The pen is connected via Bluetooth to our *Mobile Application* and tracks its position on paper by recognising a microdot pattern with a tiny built-in IR camera. This data is then transferred onto the digital twin in the mobile application in real time. The input is mapped to the form fields in the same manner as the stylus input in the digital form. To this end, the paper form has two calibration points at the corners. During the setup, their coordinates are matched by the mobile app to calculate the necessary shifting or scaling coefficients.

[3]http://www.myscript.com
[4]https://neosmartpen.com/product-n2/

2.3 Backend

After the user completes filling out a form, it is stored on the device and can be sent to the backend. We provide a lightweight Flask server that runs on a separate personal computer. Hereby, two data representations are created simultaneously: A single PDF document with all the digital ink and sketches, and an XML file containing all the information in a structured format so that knowledge-based information systems can easily use the relevant data. Further, the image annotations are exported as shapes and strokes with the exact locations within the image.

3 APPLICATIONS

We have tested and used FormTwin for data collection in our research across multiple studies. In [7], we used FormTwin to collect user handwriting along with metadata, such as gender and age, for our pilot study on author verification. In [1], we investigated whether digital pen signals can predict task difficulty and task performance among elementary school children: they were instructed to perform two standardised cognitive tests based on drawing tasks using a digital smart pen on plain paper. In a series of studies [9, 12, 13], it was indicated that FormTwin facilitated recording paper-pencil-based neurocognitive assessments for dementia screening and the deployment of digital versions of multiple neuropsychological tests; FormTwin allowed immediate data digitisation as well as processing, and was found to have no influence on neurocognitive test results; moreover, the experimenter was able to monitor the state of the process remotely in real-time on a tablet. In addition, an early prototype of FormTwin was used to collect data from radiology medical trials [10, 11, 14] to simplify the creation of reports with minimal overhead on traditional form-filling processes and provide direct ontology-based structuring of the user input for semantic search and retrieval applications.

4 CONCLUSION

In this paper, we presented FormTwin, a tool that enables data collection in a paper-based or digital format, depending on task and research characteristics. With FormTwin, existing paper forms can be annotated to create a digital twin. Then, data can be collected via two input channels: A digital form with a stylus and a tablet, as well as printed paper-based forms with a digital smart pen that is connected to the mobile application. The tool supports different data types, such as handwriting and free-from sketches, as well as checkboxes and radio buttons, which are transferred to the digital twin in real time. We described the different elements of FormTwin and briefly discussed published studies that used FormTwin for different research purposes, e.g. educational and medical use cases. FormTwin offers the flexibility of one combined solution which connects the benefits of paper-based forms regarding the collection of hand-written data, with the convenience of digital forms regarding data accessibility. With that, it supports both digitisation and digitalisation of data collection for practitioners.

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REFERENCES

[1] Michael Barz, Kristin Altmeyer, Sarah Malone, Luisa Lauer, and Daniel Sonntag. 2020. Digital Pen Features Predict Task Difficulty and User Performance of Cognitive Tests. In *Proceedings of the 28th ACM Conference on User Modeling, Adaptation and Personalization (UMAP '20)*. Association for Computing Machinery, New York, NY, USA, 23–32. https://doi.org/10.1145/3340631.3394839

[2] Madhurima Das, May Huang, and Maria Yang. 2023. Paper or Tablet? The Impact of Digital Tools on Sketching During Engineering Design Concept Generation. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Vol. 87349. American Society of Mechanical Engineers, V006T06A015.

[3] Frederic Ehrler, Guy Haller, Evelyne Sarrey, Magali Walesa, Rolf Wipfli, and Christian Lovis. 2015. Assessing the Usability of Six Data Entry Mobile Interfaces for Caregivers: A Randomized Trial. *JMIR Human Factors* 2, 2, e4093. https://doi.org/10.2196/humanfactors.4093 Company: JMIR Human Factors Distributor: JMIR Human Factors Institution: JMIR Human Factors Label: JMIR Human Factors Publisher: JMIR Publications Inc., Toronto, Canada.

[4] Robert Fleischmann, Anne-Marie Decker, Antje Kraft, Knut Mai, and Sein Schmidt. 2017. Mobile electronic versus paper case report forms in clinical trials: a randomized controlled trial. *BMC Medical Research Methodology* 17, 1 (Dec. 2017), 153. https://doi.org/10.1186/s12874-017-0429-y

[5] Robert Fleischmann, Julian Duhm, Hagen Hupperts, and Stephan A. Brandt. 2015. Tablet computers with mobile electronic medical records enhance clinical routine and promote bedside time: a controlled prospective crossover study. *Journal of Neurology* 262, 3 (March 2015), 532–540. https://doi.org/10.1007/s00415-014-7581-7

[6] Jeff Johnson and Kate Finn. 2017. *Designing user interfaces for an aging population: Towards universal design*. Morgan Kaufmann.

[7] Konstantin Kuznetsov, Michael Barz, and Daniel Sonntag. 2023. Detection of contract cheating in pen-and-paper exams through the analysis of handwriting style. In *Companion Publication of the 25th International Conference on Multimodal Interaction (ICMI '23 Companion)*. Association for Computing Machinery, New York, NY, USA, 26–30. https://doi.org/10.1145/3610661.3617162

[8] Craig Leisher. 2014. A Comparison of Tablet-Based and Paper-Based Survey Data Collection in Conservation Projects. *Social Sciences* 3, 2 (2014), 264–271. https://doi.org/10.3390/socsci3020264

[9] Alexander Prange, Michael Barz, Anika Heimann-Steinert, and Daniel Sonntag. 2021. Explainable Automatic Evaluation of the Trail Making Test for Dementia Screening. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3411764.3445046

[10] Alexander Prange, Danilo Schmidt, and Daniel Sonntag. 2017. A Digital Pen Based Tool for Instant Digitisation and Digitalisation of Biopsy Protocols. In *2017 IEEE 30th International Symposium on Computer-Based Medical Systems (CBMS)*. 773–774. https://doi.org/10.1109/CBMS.2017.132 ISSN: 2372-9198.

[11] Alexander Prange and Daniel Sonntag. 2016. Digital PI-RADS: Smartphone Sketches for Instant Knowledge Acquisition in Prostate Cancer Detection. In *2016 IEEE 29th International Symposium on Computer-Based Medical Systems (CBMS)*. 13–18. https://doi.org/10.1109/CBMS.2016.23 ISSN: 2372-9198.

[12] Alexander Prange and Daniel Sonntag. 2021. Assessing Cognitive Test Performance Using Automatic Digital Pen Features Analysis. (June 2021), 33–43. https://doi.org/10.1145/3450613.3456812

[13] Alexander Prange and Daniel Sonntag. 2022. Modeling Users' Cognitive Performance Using Digital Pen Features. *Frontiers in Artificial Intelligence* 5 (May 2022). https://doi.org/10.3389/frai.2022.787179 Publisher: Frontiers.

[14] Daniel Sonntag, Markus Weber, Alexander Cavallaro, and Matthias Hammon. 2014. Integrating Digital Pens in Breast Imaging for Instant Knowledge Acquisition. *AI Magazine* 35, 1 (March 2014), 26. https://doi.org/10.1609/aimag.v35i1.2501

[15] Alissa Tate and Claire Smallwood. 2021. Comparing the efficiency of paper-based and electronic data capture during face-to-face interviews. *PLOS ONE* 16, 3 (March 2021), e0247570. https://doi.org/10.1371/journal.pone.0247570 Publisher: Public Library of Science.

[16] Chen Hsi Tsai, Aboozar Eghdam, Nadia Davoody, Graham Wright, Stephen Flowerday, and Sabine Koch. 2020. Effects of Electronic Health Record Implementation and Barriers to Adoption and Use: A Scoping Review and Qualitative Analysis of the Content. *Life* 10, 12 (Dec. 2020), 327. https://doi.org/10.3390/life10120327 Number: 12 Publisher: Multidisciplinary Digital Publishing Institute.