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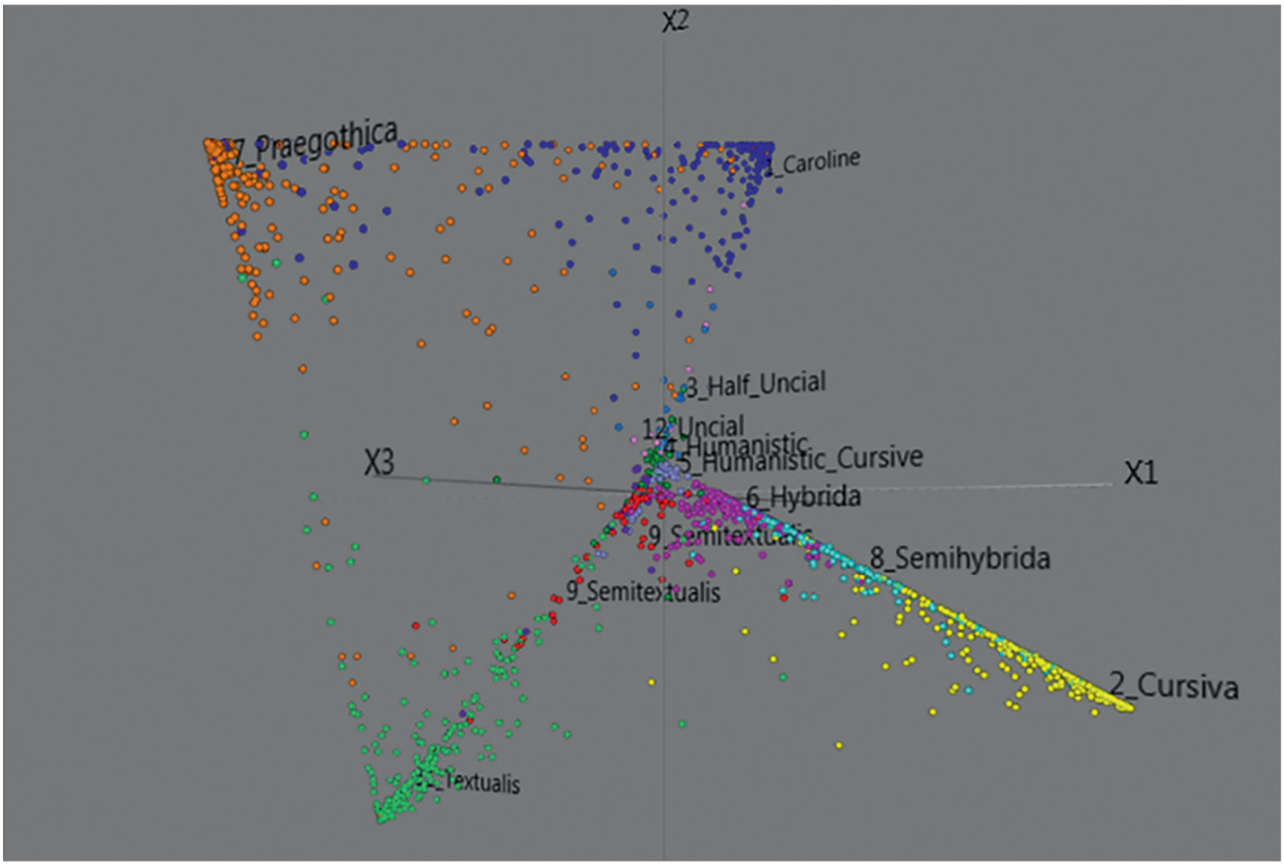


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**Editors**
Prof. Dr Michael Friedrich
Universität Hamburg
Asien-Afrika-Institut
Edmund-Siemers-Allee 1/ Flügel Ost
D-20146 Hamburg

Tel. No.: +49 (0)40 42838 7127
Fax No.: +49 (0)40 42838 4899
michael.friedrich@uni-hamburg.de

Prof Dr Jörg Quenzer
Universität Hamburg
Asien-Afrika-Institut
Edmund-Siemers-Allee 1/ Flügel Ost
D-20146 Hamburg
Tell. No.: +49 40 42838 - 7203
Fax No.: +49 40 42838 - 6200
joerg.quenzer@uni-hamburg.de

www.csmc.uni-hamburg.de

**Editorial Office**
Dr Irina Wandrey
Universität Hamburg
Centre for the Study of Manuscript Cultures
Warburgstraße 26
D-20354 Hamburg
Tel. No.: +49 (0)40 42838 9420
Fax No.: +49 (0)40 42838 4899
irina.wandrey@uni-hamburg.de

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Miriam Gerdes

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# CONTENTS



## ARTICLES

Article

# Turning Black into White through Visual Programming: Peeking into the Black Box of Computational Manuscript Analysis

**Vinodh Rajan Sampath and H. Siegfried Stiehl | Hamburg**

Abstract

In the recent past, an ever-increasing plethora of computational methods and tools for computational manuscript research, and by extension digital palaeography, have been developed and provided by the scientific community of digital image processing and analysis (or, in a wider sense, computational vision). Invariably, however, many of these methods and tools suffer from low usability from the point of view of humanities scholars, the actual end users. The black box problem is the most commonly cited reason for this sheer fact. While it may not be possible to completely eliminate the problem, we can alleviate it by dismantling the computational black box into smaller boxes and eventually turn them white. We discuss how visual programming as a paradigm will make peeking into the computational black box possible. In this context, we introduce the iXMan_Lab and AMAP, a collaborative web-based platform that facilitates the development and experimental validation of tools and workflows using an innovative visual programming paradigm. We will also briefly relate our approach to design thinking and open science.

## 1. Introduction

### *1.1 Computing in the context of interdisciplinary manuscript research*

With the recent advances in the theories, methods and applications of various computational methods (pertaining to digital image processing, analysis and archiving – among other things) in the humanities and the consequent emergence of digital humanities as a scientific discipline, we are witnessing a burst of tools enabling digital palaeography and the thorough multi-facetted understanding of manuscripts. Even though a wide variety of these methods and tools aim to support scholarly work in computational manuscript research (CMR), only a few of the tools have found widespread and consistent acceptance and use (particularly in the case of digital palaeography). The reasons can be outlined as follows.

Most of the tools that are assumed – or even claimed – to be readily applicable to questions and problems in manuscript research were developed solely from the point of view of information science and often fail to take the specific requirements of cognizant end-users into account who work in a specific domain of humanities-based manuscript research. The main consequence of involving the humanities to such a small extent in tool design is that users in such fields have difficulty understanding or employing the computer-based solutions (software tools) in their target domain. As a consequence, tools appear as black boxes (Hassner et al. 2014), acutely affecting their usability and usefulness. Frequently, users do not understand how or why the tools behave and perform in a certain way and as a consequence they question the results produced. In addition, they cannot influence or change the way the tools behave, because they cannot understand the way individual tools (or their chained aggregation to a fully-fledged system) work. With only a parochial – or even no – way to understand, test or influence the underlying theories and computational methods, many of the tools end up being unusable in an academic/scientific setting (Stokes, 2012). As an important consequence, an inter-/transdisciplinary approach has to be taken, which first demands a genuine methodology for building bridges between i) humanistic manuscript research primarily grounded in hermeneutics and ii) computational manuscript research grounded in algorithmics.

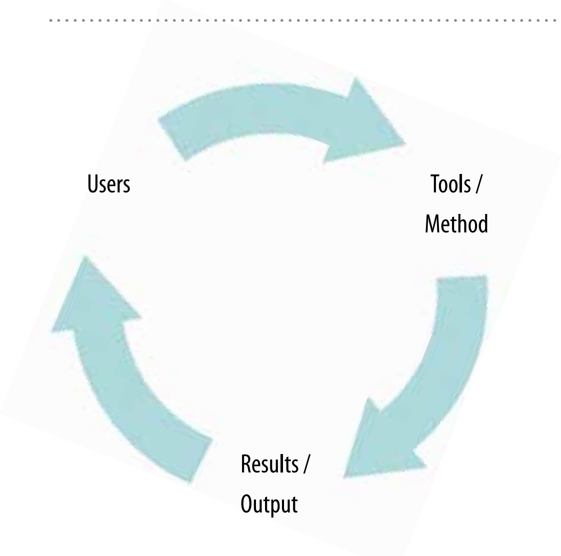


Fig. 1: A simplified user-in-the-loop system.

*1.2 Document Image Analysis*

According to Kasturi et al. (2002), document image analysis (DIA) consists of 'algorithms and techniques that are applied to images of documents to obtain a computer-readable description from pixel data methods'. In our context, the general term 'documents' refers to either contemporary or historical prints and manuscripts, while 'images' is synonymous with 'digitized manuscripts'. DIA methods such as image pre-processing, keypoint detection, visual feature extraction, text line finding, page layout analysis, writing style analysis and hand identification are employed within computational manuscript research for a wide variety of purposes ranging from simple image quality enhancement to increased legibility to advanced applications such as writer identification for palaeographic dating. Given the stage of research in computational vision, however, it is safe to state that tools for particular tasks and domains cannot be directly derived from published theories and methods for at least two reasons: almost all methods entail parameters that have to be carefully adapted to the particular task and domain at hand and, worth noting, the accuracy, reliability and robustness of their performance greatly depends on the quality of the digitized image (e.g. resolution and contrast, as well as degradations such as noise). In a strict sense, also methods or services from open source repositories (such as GitHub) are hardly applicable to a specific task in a, say, blind fashion – let alone the myth of error-free software. Consequently, for computational vision, the real issue is multifaceted and multi-staged: from theory to algorithms to methods to experiments to tools to services and systems – in total with the aim of supporting the workflow of humanities scholars involved in their hermeneutic research methods. Since computer-assisted manuscript research on the basis of tools also requires thorough validation, evaluation and benchmarking of methods and tools from above, scientifically grounded – but, alas time-consuming – experimentation with synthetic, real and ground truth data is indispensable, if only, e.g. to constrain the space of parameters and understand the propagation of errors through a chain of methods. Last but not least, two more critical aspects have to be mentioned: first, the lack of a clear-cut methodology and thus also any engineering approach to consistently link the realm of theory with the reality of workflow support for scholars and, second, the involvement or even embedding of affected scholars in the whole, notably cyclic, process of requirement analysis, system design, realization, evaluation and re-design, as well as the provision and maintenance of performing, web-based, interoperable and platform-independent tools. Clearly within contemporary informatics, such an integral approach has design thinking including advanced, e.g. agile, software design and development as one of its pillars and lays foundations for a methodology that is not only desirable, but much needed.

Many of the tools, simply speaking, can be considered to be a composite of various DIA methods. However, such a composition is not as simple as it may appear to a layman, and the resulting tools require proper consideration in terms of building blocks, or sub-modules, and their connectedness, parameter regimes, applicability and appropriate presentation of results, among other things (see above). Many of these building blocks are not exposed to end users, and even if exposed, do not provide a meaningful way of interaction to truly keep the user in the loop and in control. This invariably results in a composite tool becoming a monolithic black box that end users have trouble interacting with and trusting.

*1.3 User-in-the-loop paradigm*

User-in-the-loop as a paradigm (Hassner, 2013) is often suggested as a work-around to resolve many of the critical issues mentioned above (Fig. 1). In general, it attempts to give more control to users by i) opening up the tools to further useful and purposeful interaction, ii) having more control over the range, scale and configuration of methods and iii) even providing feedback for improvement of e.g. overall performance. The main idea here is to i) involve, not to say embed or even immerse, users – who are experts from their respective fields – in the cyclic process sketched in the best possible way and ii) metaphorically speaking, make them part of the algorithm and the methodology. Thus, what is in order is transforming the tools from being computational

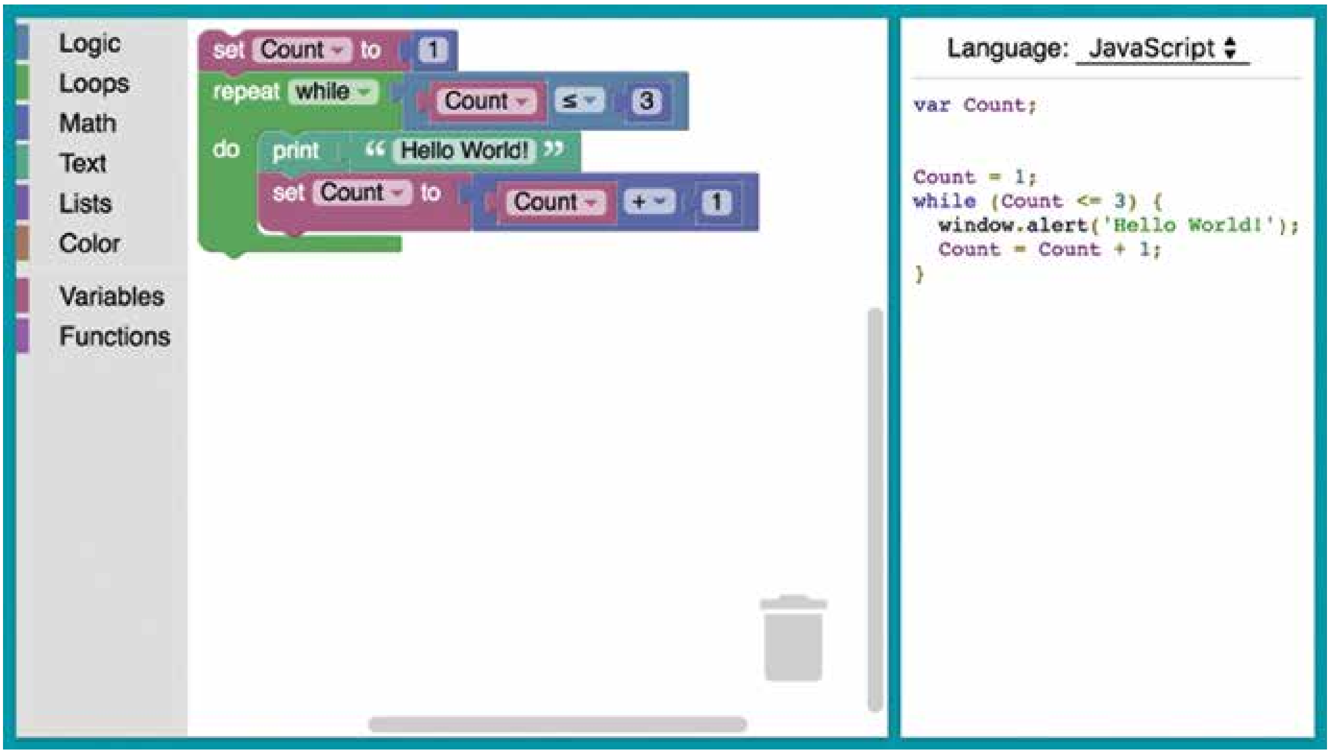


Fig. 2: Google Blockly.

soothsayers that take in data and render the divination of results towards actually performing, reliable and trustworthy systems that work in tandem with users, taking into serious consideration their needs, alterations and feedback. From the point of view of *conditio humana*, a tool (or computer in general) should serve a human and not vice versa. Hence, a scholarly expert in manuscript research should by no means be demeaned or vilified by a technologically allotted role as key puncher or mouse clicker (see below).

While we adopt the user-in-the-loop paradigm as the right and principal approach to open up the seeming black box, the paradigm appears quite late in the software engineering process. We strongly propose that gaining an understanding of the black box must ideally occur quite early in the whole process outlined so far, and in fact, this would mean that, ideally, users must be involved in the initial stages of the process of designing and building tools, as well, and not just in the final stages of using them, be it for experimental or practical purposes. This allows users to i) get an idea of what exactly goes into the tools and ii) garner a better understanding of the final tools or even system, including internal components, performance characteristics, degrees of freedom, parameter sensitivity etc. As will be argued below, the adoption of visual programming (VP) as a tool-building paradigm will enable us to accomplish the goals laid out above in an efficient, effective and user-friendly way.

### *1.4 Visual programming*

Visual Programming (VP) is a novel, pioneering programming paradigm that allows users to develop computer programs by spatially arranging software modules, or computational methods in our case, as graphic symbols, typically in two dimensions, e.g. on a monitor or screen (Myers, 1990). Hence, users are enabled to build programs by putting together computational 'Lego'-like blocks on a screen, or even a multi-touch table as in our case, in an interactive fashion. The graphic symbols can be either low-level, containing only control structures and variables, or, optionally, high-level, supporting various abstract modules relevant to the application domain. Several types of VP paradigms have been made available so far, the most popular ones being block-based and graph-based or flow-based VP languages. Blockly (Fraser, 2015) and AppInventor (Wolber, 2011) are block-based visual languages that allow users to arrange and fit various blocks into predefined slots and holes to create programs (Fig. 2). Differently, Microsoft Visual Programming Language is a flow-based visual language that allows users to define programs as a graph using nodes and edges, with the nodes usually denoting some sort of processing and the

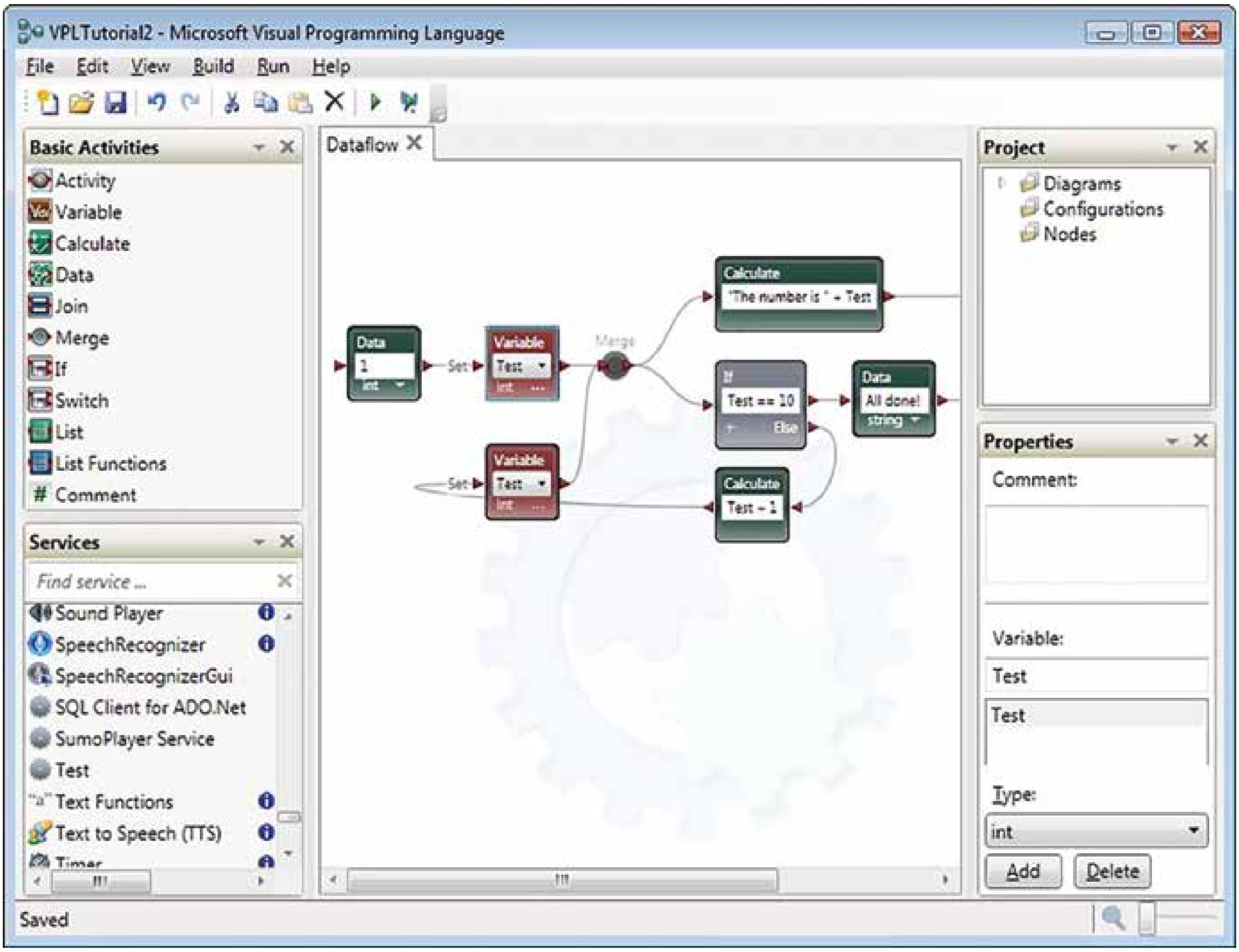


Fig. 3: Microsoft Visual Programming Language.

edges the in- and out-flow of data. Although indeed several other VP paradigms do exist, they are neither very popular nor relevant to our current research span (Fig. 3).

VP is becoming a popular programming paradigm in various domains, particularly in education to teach programming concepts and in Do-It-Yourself (DIY) environments for domain specialists to create both programs and workflows. VP allows specialists to create (or at the minimum, to co-create) solutions to well-defined domain problems in an easy and interactive way without the overhead of learning a mainstream textual programming language. A prominent example of the latter would be AppInventor, which provides a VP language and the necessary environment to develop web apps without the need for any programming experience.

## 2. Peeking into the black box

To properly eliminate, or at least alleviate, the black box problem, one has to completely understand the mathematical and functional limitations of all the computational methods that make up a tool or system. Often, this is achievable only if the tool developers have a strong mathematics background, particularly when it comes to advanced DIA methods (see above) and even more cutting-edge methods, e.g. stemming from the research field of machine learning (ML) and, particularly, deep learning (DL) in layered neural networks, which are frequently claimed to be black boxes per se due to their lack of accountability and transparency (or, in a strictly algorithmic sense, lack of proof of correctness and uniqueness). While it may not be possible to completely eliminate the black box property itself, it is feasible to deconstruct it into multiple smaller entities, which themselves could nevertheless be black boxes, thereby reducing complexity to a level of better transparency and, thus, understanding. This allows both peeking into the seeming black box and being able to conceive the multitude of interconnected parts contained within it. On a practical level, sometimes it is just enough if one understands

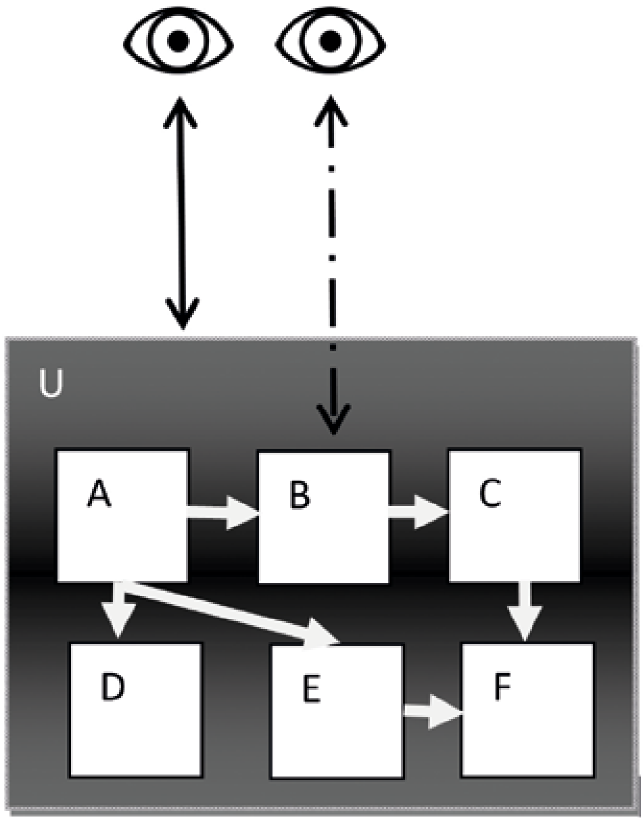


Fig. 4: Users usually only see the overall system *U*. But it is necessary that they also know about the subsystems.

the different components that make up a hierarchical or trivially sequential system and how they interact with each other (e.g. via linking data or cross-effects of parameters, as in the simple case of a typical image processing pipeline for easy tasks). Evidently, in such cases, a great deal of understanding can be easily provided. This is required in order to understand the overall workings of the system and, accordingly, to tailor or streamline it towards compliance with user requirements. The opaque nature of the decomposed subcomponents can further be reduced by exposing their working through appropriate visualization techniques (Fig. 4).

Again, due to the preponderance of non-trivial and non-mainstream scientific problems in interdisciplinary computational manuscript research, e.g. generic layout analysis or hand identification given abundant degradations in digitized manuscripts, sparseness of training data and the lack of ground truth and benchmarks far from a scholar's workflows, the demanded tools and systems are complex in theoretical, methodical, technical and human-factor terms, which is far different from 'toy' problems such as recognizing cats and dogs or preventing a moving robot from ramming a table leg (though these *are* engineering feats).

As already mentioned, with the rise of methods of training data-intensive deep learning (DL), it simply is more difficult or even virtually impossible to open up such systems, as a sufficiently deep neural network is itself a black box from both a theoretical and an algorithmic perspective. However, even DL tools are not always monolithic, since some kinds of pre-processing and post-processing steps almost always go along with the core DL method. Hence, on-going research in the respective communities is about to open these as much as possible again for the sake of a better understanding by both the developers and the users – particularly in the context of applications that require trustworthy computational results, as in signature verification. Although scientific problems with CMR may well be characterized as non-critical (e.g. in comparison with fraud detection), accountability, transparency, trustworthiness etc. are still for good reason key features of tools and systems – otherwise the willingness of scholars to use them in their daily routine will fade or not even be kindled. On top of that, by briefly touching upon issues of accuracy, reliability, replicability etc., an added-value of any CMR tool/system devoted to help solve scholarly research questions must be clearly demonstrated – otherwise it's l'art pour l'art.

As already mentioned, a VP environment can be helpful in deconstructing computational black boxes by taking two different approaches. In the first approach, a VP-based DIY environment can be provided to manuscript scholars in the humanities. It is seldom possible to provide specific computational solutions that are generalizable and applicable to scenarios with problem settings that scholars face on a day-to-day basis. Therefore, we would do better to focus on providing them with genuinely required toolsets that would let them i) explore various methods on their own, ii) deal with digitized manuscripts and iii) create custom-built solutions by themselves in an interactive way using the VP paradigm. They can choose various techniques, explore them and assemble them to produce solutions in accordance with their needs. Needless to say, a certain training of CMR novices and/or IT affinity is presupposed even in this ideal conception. In the second approach, a VP-like environment is used as part of the software engineering methodology to interact and communicate with scholars from the humanities. By using such an environment, experts from informatics are enabled to discuss/develop various solutions effectively by i) providing the scholars with a hands-on interactive experience in solution building and ii) granting them a co-creating role. Rajan and Stiehl (2018b) coined the term 'interactive Exploration (iX)' for this approach and discussed it in great detail as part of a software/system development methodology (SDM) for tools in CRM. In both approaches, users (in our case manuscript scholars in the humanities) dismantle the monolithic black-box-like solutions either by themselves (in the first playful approach) or by jointly working in tandem or on a team with CMR experts who are sufficiently knowledgeable in computational vision (as in the second, more principled approach by explicitly constructing solutions as an assembly of more basic subcomponents in order to gain an understanding of their interaction and, hence, the overall functionality of the system).

Even in the worst case, in which users are not able to participate in the tool creation process, VP-like features can still be used to i) create an effective visualization of the final tool structure and functionality and ii) communicate the overall working mode and scope of the tool to the end users. Not only will this still help make the black box at least translucent, but it can also be used as a teaching and training environment for students and up-and-coming academics with a strong interest in CMR.

## 3. Using visual programming to turn the black box white

Below, we elaborate on how various features and properties of VP enable the dismantling process and also facilitate further opening up the black box in various other ways.

### *3.1 General advantages of visual programming*

Visual programming offers several advantages over textual programming. Blackwell (1996) notes that 'typical statements are that VP is more user friendly, helpful, satisfying, intuitive, readable, familiar, appealing, accessible, reliable, pleasant, straightforward, alluring, immediate and obvious than other programming techniques'. As such, VP encourages non-programmers to play around with its visual elements, letting them explore and freely experiment with digital objects to attain their desired programming objectives. A functional computer program can thus be created in a short time by merely placing some graphic objects in an orderly manner. Also, a solution produced in a VP language can (under certain circumstances) be more understandable and communicable than a solution produced in a textual language.

One of the main advantages relevant to our problem setting in CMR is that VPs are better at expressing the problem structure. Their diagrammatic nature coupled with the semantic spatial arrangement enables users to better grasp the structures of a reasonably complex solution. The other major advantage is its resemblance to the real world of a particular application stemming from hermeneutic manuscript research. By mimicking the real world in its visual representation, a VP language can map the manipulation of real-world objects to those of digital objects by choosing an appropriate interaction metaphor. Such factors are advantageous in minimising the black-box problem by enabling users to better understand the intricacies of the tool or system.

### *3.2 Specific features of visual programming*

As a paradigm, visual programming attempts to implement four core features: concreteness, directness, explicitness and liveliness (Burnett, 2002). In the following, we explore how these specific features can help to open up the computational black box with specific references to creating tools in CMR.

#### 3.2.1 Concreteness

Concreteness means expressing programmatic aspects using particular instances, e.g. mapping some aspect of semantics to desired behaviour using a specific object or property. A black and white brush realized as a tool could denote a binarization process (i.e. turning colour images into black and white) and the size of the brush could be directly proportional to the threshold of binarization (i.e. pixels below a certain threshold become white). Thus, we are mapping abstract methods such as binarization onto concrete graphic entities in a VP environment. By converting the abstract into concrete, users get a better grasp (also in the physical sense of the word) of the inner workings of a tool.

#### 3.2.2 Directness

Directness can be described as 'the feeling that one is directly manipulating the object', which implies a minimal distance between an objective and the actions required to achieve it. This is usually implemented by choosing an appropriate interaction paradigm that maps the digital objects to appropriate real-world metaphors. To continue the previous example, binarizing a digital image could be implemented by moving a brush over the image. This allows users to intuitively interact with the system directly and make changes.

3.2.3 Explicitness

The internal aspects of a system are made visually explicit, enabling users to infer these aspects intuitively. Particularly in our context, this means making dataflow, e.g. in a chain of computational methods, explicit by visualizing the intermediates and also making parameters associated with various methods explicitly visual for direct control. By exposing the various methods, parameters, dependencies and interconnectedness of the components by the use of graphic objects and visual metaphors, users get a better understanding of the overall tool or system for CMR.

3.2.4 Liveness

The immediacy of feedback that is automatically provided by a program, tool or system is termed liveness. Tanomoto (1990) enumerates four levels of liveness. The first level corresponds to the static visual representation of the system and is by no means interactive. It is meant to be only a diagrammatic representation to help the user understand the structure and flow of a program. CMR tools must strive to provide at least this level of liveness, even if they do not use the VPL paradigm. In the second level of liveness, the system is interactive, and users are able to build the system with graphic elements and run the system to view the results. But users must explicitly execute the setup to view the results. In the third level, the users need not explicitly run the system whenever something is changed, since the system automatically runs in response to changes initiated by users. This encourages scholars to explore and try out different combinations, e.g. sub-modules and parameters and get immediate feedback. In the last level of liveness, the system is always on and provides temporal feedback based on the current state of the system. This can be very relevant for DL systems that typically take a long time to train or any system that handles high-volume data streams. Continuous visual feedback will keep the users engaged and involved by providing a glimpse of the current set and state of running processes, such as computational methods, along with their intermediate results, depending on the parameter settings. Also, e.g. in the case of experimentation with CMR tools in the iXMan_Lab, it is useful to keep full track of progress by compiling a comprehensive lab logbook in order to conform to standards in scientifically grounded experimentation (as known from paragons in experimental physics, psychology and the social sciences).

## 4. iXMan_Lab

In these CMR, DIA and VP contexts, we now introduce the *iXMan_Lab* (interactive eXploration of Manuscripts Laboratory), whose realization is one of the goals of the Scientific Service Project Z03 of the SFB 950. The underlying motto for the laboratory is to develop concepts, paradigms and prototypes that contribute to the realization of usable and useful CMR tools for manuscript scholars, which they can use in their work activities, as discussed earlier. More specifically, not only methods and tools being developed within Z03, e.g. for word spotting and writing style analysis (see e.g. HAT 2.0), but also open source methods and tools (e.g. from OpenCV; see also OpenX Workshop[1] of June 2018), as well as web-accessible services from various sources (see e.g. DIVAServices of Université de Fribourg), will be integrated in order to enhance the current scope of functionality. Web access to the lab is assured due to interoperability and platform independence – also meaning ubiquity of CMR functionality for scholars outside the Department of Informatics (as current lab host) who are equipped only with standard IT equipment such as desktop computers, laptops or tablets (whereby touch-based devices are preferred).

The lab is driven by an interdisciplinary team using a multi-touch table environment (powered by high-performance computing equipment) as a collaboration, cooperation and communication (C3) medium for a two-fold aim: first, experimentally designing a manageable, feasible and reliable processing chain based on computational vision methods for processing/analysing digitized manuscripts and, second, freezing in a jointly validated (or even evaluated or benchmarked) processing chain by interdisciplinarily reached consensus in order to deliver a useful tool for a broad range of users. In terms of hardware infrastructure, the laboratory is currently equipped with a custom-built 65-inch Multi-Touch Table (MTT) supported by a high-performance multi-core gaming engine. The MTT is additionally adjustable to a wide range of height and angle settings to enable various forms of team collaboration. The laboratory is completely equipped to run both GPU-accelerated image processing/

[1] Centre for the Study of Manuscript Cultures <https://www.manuscript-cultures.uni-hamburg.de/register_openx2018.html>.

Fig. 5: The MTT setup in iXMan_Lab.

analysis algorithms and, if necessary, deep learning methods (Fig. 5).

Even though primarily situated within the Department of Informatics as mentioned above, the lab is uniquely placed within the Centre for the Study of Manuscript Cultures, the host of SFB 950, and is able to web-interact with various scholars from sub-projects of SFB 950. In sum, the laboratory, once fully-fledged, will enable scholars to i) perform meticulous requirement engineering, ii) design and realize experiments and iii) provide workflow-supporting tools due to the close interaction between scholars from Manuscript Studies and Informatics.

## 5. Advanced Manuscript Analysis Portal (AMAP)

Currently, the main focus of the iXMan_Lab is the further development of the *Advanced Manuscript Analysis Portal* (AMAP), whose conceptual development started in 2015 in the Scientific Service Project Z03 with the beginning of the second funding phase of the SFB. Rajan and Stiehl (2018a) gives a first outline of the design, architecture and functionality of AMAP, which is equipped with an intuitive interaction paradigm in the context of a multi-touch table. In brief, it will allow users to i) intuitively deal with various advanced image processing/analysis methods and other manuscript-related methods and ii) create their problem-specific (and thus customized) chains of computational methods. The general goal is to design and develop AMAP in such a way that even advanced methods can be applied in an easy and intuitive manner by scholars without any programming and only rudimentary technical background. Furthermore, we are designing AMAP to be able to encourage and foster the exploration of various methods, tools, services and workflows and, at the same time, to enable ease-of-use without any steep learning curve. AMAP ultimately aims to provide a VP-based environment and to support both approaches to deconstructing the black box (as discussed in section 2). It can serve as both a DIY-like environment for scholars working in the humanities and at the same time as an experimental platform for facilitating the interaction and communication of interdisciplinarily constituted teams from the humanities and informatics during the software development process.

We particularly chose to realize AMAP via an MTT, as touch-based technology is gaining huge traction and has the potential of becoming the primary mode of interaction in the near future. Even today, touch-based interfaces are becoming increasingly popular, compared with the traditional Windows/icons/mouse/pointers-based interfaces (WIMP). Also, having a large-scale interaction/interface area available is necessary when interacting with multiple high-resolution images, which is usually the case when analysing digitized manuscripts. The MTT can be further augmented to allow multiple input modalities that could be harnessed to make the system even more natural through its ability to model and mirror physical real-world interaction, e.g. by speech and deixis, with manuscripts as much as possible. An MTT is also an ideal medium to encourage real-time collaboration in a team of scholars from the humanities and informatics through the provision of a sharable, large-scale, monitor-based interaction device.

AMAP currently offers a rich selection of various functionalities such as image filtering, binarization, visual feature detection, word spotting, page layout analysis and writing style analysis (Mohammed et al. 2017). In fact, multiple methods providing the same functionality are also included to enable users to experiment and choose a method that is best suited to their task at hand. Our system also offers the ability to integrate other backend systems that provide DIA techniques as web-based services. This has been realised by integrating methods available at DIVAServices (Würsch et al., 2016) as part of AMAP. Such integrations demonstrate the flexibility of our approach, as well as the ability to assimilate wide-ranging manuscript-related computational methods from the OpenX community (where X stands for data, methods, tools, services etc. in accordance with the Open Science paradigm) into our platform.

### *5.1 VP and AMAP design*

We are currently implementing an innovative hybrid VP language that integrates both a flow-based approach and a block-based approach. The paradigm works on the principle of visualizing the digitized documents and computational methods as virtual objects that can be manipulated spatially in relation to each other in order to aggregate various processing chains, e.g. in the context of experimentation and/or to create task- and problem-specific workflows for scholars from the humanities. The user interface (UI) in particular is designed to reflect real-world metaphors as much as possible in terms of interaction. Users can i) directly attach/detach various methods to/from the digitized manuscripts before and during chaining to processing pipelines and ii) manipulate parameters and subsets of manuscripts to process them even further. Additionally, the UI also supports natural interaction including actions such as piling the pages and turning them to take notes.

Fig. 6 shows a sample screenshot of a rather simple processing chain that has been realized with AMAP for demonstration purposes. It includes a textline detection method that requires a binarization step beforehand as pre-processing. Instead of being a single block, this decomposition explicitly shows that the quality of the textline detection is at least partially dependent on the pre-processing step, and by controlling the pre-processing step the quality of the results can be adjusted to the user's need. Also, by adding several other pre-processing steps, the results can be improved even further through goal-directed experimentation. The user is able to have some control over the system and understand how the process works, as opposed to a single processing block that provides only the output to a given input. Furthermore, a detected single textline from the output can also be seen to be extracted as a subset and a filter can be applied to it, specifically to increase its readability. One can also see a digital logbook recoding all previous operations performed with AMAP along with their timestamp and parameters of the operations.

## 6. Conclusion

We reported on the current state of computational manuscript research (CMR) and the inherent black box problem that particularly results in low acceptance of computational tools in scientific settings within scholarly manuscript research in the humanities. We proposed to alleviate the black box problem by dismantling the computational black box(es)

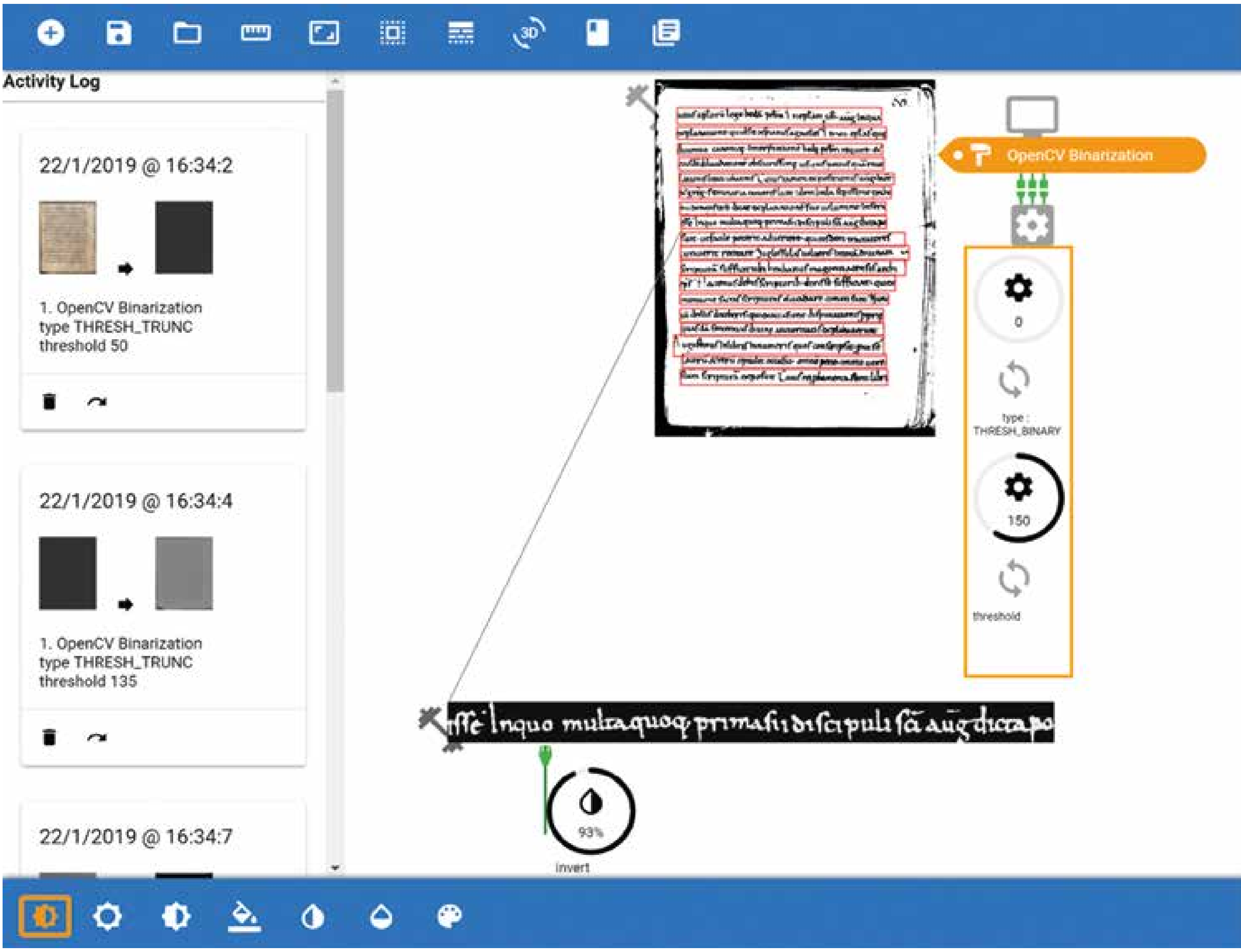


Fig. 6: AMAP Prototype.

into smaller, thus transparent and tractable, elements through visual programming in order to keep the user in the loop and in control – either during experiment-based configuration of processing chains for specific tasks or in the collaboration-driven design of workflows for solving scholarly problems of manuscript research in the humanities. The advantages of VP and its various features that enable the effective dismantling of the black box problem were elaborated in detail. Moreover, we embedded our design and realization approach in the broader context of software development methodology inspired also by design thinking and human computer interaction/communication. We finally introduced our iXMan_Lab concept and AMAP as its tool instance, a web-based prototype tool that attempts to deconstruct the black box by offering potential users from SFB sub-projects various DIA methods in a supportive VP environment. Our adoption of at least some of the principles of the VP paradigm to deconstruct the computational black box is the first step in the long journey ahead to completely eliminate the black box for the sake of truly inter-/transdisciplinary, effective and efficient computational manuscript research.


## ACKNOWLEDGMENTS

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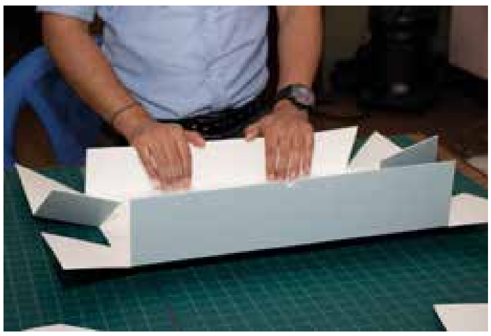

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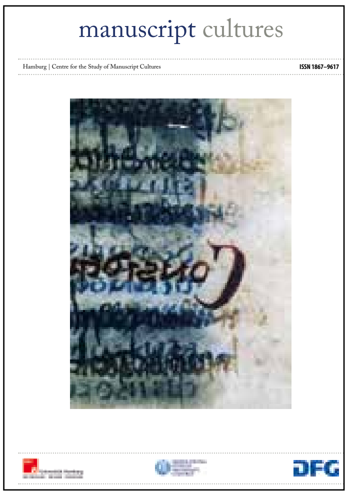


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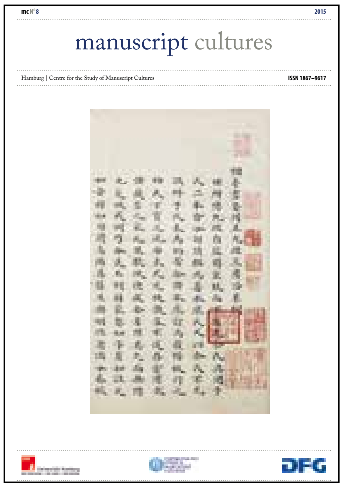


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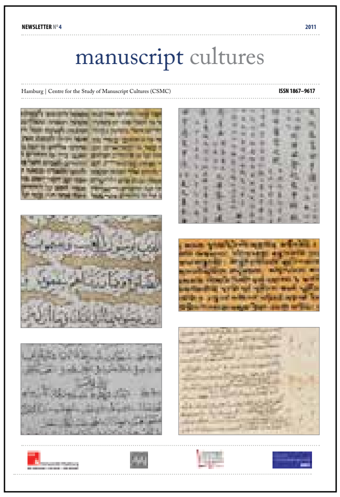

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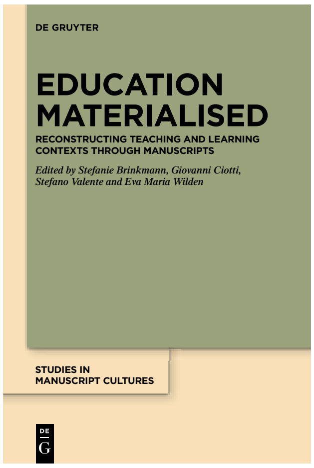


23 – *Education Materialised: Reconstructing Teaching and Learning Contexts through Manuscripts,* edited by Stefanie Brinkmann, Giovanni Ciotti, Stefano Valente and Eva Maria Wilden

Manuscripts have played a crucial role in the educational practices of virtually all cultures that have a history of using them. As learning and teaching tools, manuscripts become primary witnesses for reconstructing and studying didactic and research activities and methodologies from elementary levels to the most advanced.
The present volume investigates the relation between manuscripts and educational practices focusing on four particular research topics: educational settings: teachers, students and their manuscripts; organising knowledge: syllabi; exegetical practices: annotations; modifying tradition: adaptations.
The volume offers a number of case studies stretching across geophysical boundaries from Western Europe to South-East Asia, with a time span ranging from the second millennium BCE to the twentieth century CE.

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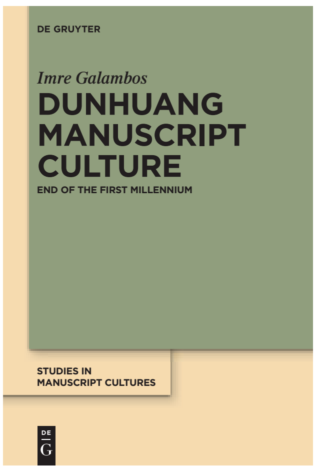


22 – *Dunhuang Manuscript Culture: End of the First Millennium,* by Imre Galambos

*Dunhuang Manuscript Culture* explores the world of Chinese manuscripts from ninth–tenth century Dunhuang, an oasis city along the network of pre-modern routes known today collectively as the Silk Roads. The manuscripts have been discovered in 1900 in a sealed-off side-chamber of a Buddhist cave temple, where they had lain undisturbed for for almost nine hundred years. The discovery comprised tens of thousands of texts, written in over twenty different languages and scripts, including Chinese, Tibetan, Old Uighur, Khotanese, Sogdian and Sanskrit. This study centres around four groups of manuscripts from the mid-ninth to the late tenth centuries, a period when the region was an independent kingdom ruled by local families. The central argument is that the manuscripts attest to the unique cultural diversity of the region during this period, exhibiting – alongside obvious Chinese elements – the heavy influence of Central Asian cultures. As a result, it was much less 'Chinese' than commonly portrayed in modern scholarship. The book makes a contribution to the study of cultural and linguistic interaction along the Silk Roads.

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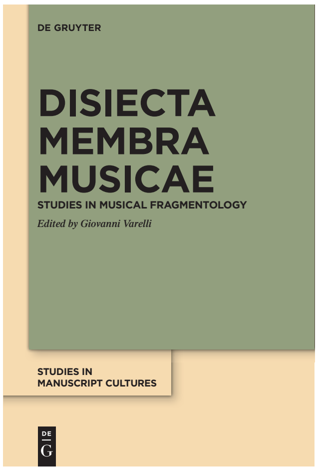


## 21 – *Disiecta Membra Musicae: Studies in Musical Fragmentology*, edited by Giovanni Varelli

Although fragments from music manuscripts have occupied a place of considerable importance since the very early days of modern musicology, a collective, up-to-date, and comprehensive discussion of the various techniques and approaches for their study was lacking. On-line resources have also become increasingly crucial for the identification, study, and textual/musical reconstruction of fragmentary sources. *Disiecta Membra Musicae. Studies in Musical Fragmentology* aims at reviewing the state of the art in the study of medieval music fragments in Europe, the variety of methodologies for studying the repertory and its transmission, musical palaeography, codicology, liturgy, historical and cultural contexts, etc. This collection of essays provides an opportunity to reflect also on broader issues, such as the role of fragments in last century's musicology, how fragmentary material shaped our conception of the written transmission of early European music, and how new fragments are being discovered in the digital age. Known fragments and new technology, new discoveries and traditional methodology alternate in this collection of essays, whose topics range from plainchant to *ars nova* and fifteenth- to sixteenth-century polyphony.

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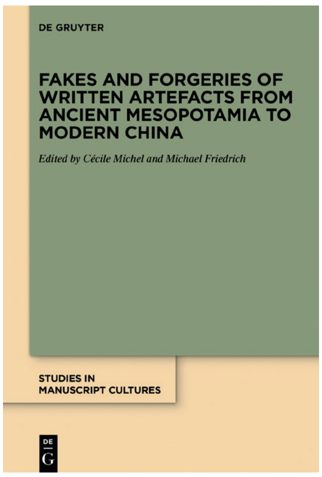


## 20 – *Fakes and Forgeries of Written Artefacts from Ancient Mesopotamia to Modern China,* edited by Cécile Michel and Michael Friedrich

Fakes and forgeries are objects of fascination. This volume contains a serie of thirteen articles devoted to fakes and forgeries of written artefacts from th beginnings of writing in Mesopotamia to modern China. The studies empha sise the subtle distinctions conveyed by an established vocabulary relating t the reproduction of ancient artefacts and production of artefacts claiming t be ancient: from copies, replicas and imitations to fakes and forgeries. Fake are often a response to a demand from the public or scholarly milieu, or eve both. The motives behind their production may be economic, political, reli gious or personal – aspiring to fame or simply playing a joke. Fakes may be revealed by combining the study of their contents, codicological, epigraphi and palaeographic analyses, and scientific investigations. However, certain fa mous unsolved cases still continue to defy technology today, no matter ho advanced it is. Nowadays, one can find fakes in museums and private collec tions alike; they abound on the antique market, mixed with real artefacts tha have often been looted. The scientific community's attitude to such objects calls for ethical reflection.

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Centre for the Study of Manuscript Cultures
Universität Hamburg
Warburgstraße 26
D-20354 Hamburg

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