Foreword

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Do historians need computers for more than writing? What could be the other uses? Does the use of computers pose a threat to history by bringing in a reductionist approach? Perhaps surprisingly to some, I would say that historians are dealing with phenomena that may be characterised as much more complex than those studied by scholars in natural sciences. This has meant that historians have had to work using educated human interpretation rather than machines or algorithms as their methodological basis. In natural sciences, it is commonplace to look for underlying simple causes even for phenomena that appear to be highly complex on the surface. Such a reductionist approach is neither wise nor productive in many areas and topics within history, because human behaviour and social organisation includes complexities like phenomena's instability as they change over time. The reliance on words of written languages and human-made images and less on numbers based on measurements, and the non-linear dependence of context and complex feedback mechanisms between society, individuals and their times further increase the intricacy of a historical study. An example of the latter is that a written document on history may itself influence the track of future events and thus history can change history. These kinds of connections are not known to exist within the natural sciences. History is different.

I have for a long time followed, participated in and had aspirations for connecting history and computer science. In the 1980s, I as a computer scientist

was using rule-based artificial intelligence (AI) methods in particular in the area of natural language processing. Thanks to my personal contacts, I had often a chance to discuss with historians their work, results and methodologies. Soon the idea came up of finding ways to build a bridge between historians and AI researchers, but after some consideration this did not seem feasible or relevant. With the rule-based AI methods, it was not possible to approach phenomena that were relevant for historians. Computer science was not sufficiently developed for historians. The challenge was both quantitative and qualitative. However, as history tells us, and this volume gives many examples of, our tools and our times change. Since the 1990s, my experience of using and developing neural networks and statistical machine learning methods has been quite different. My personal experience of applying these methods since 1991 led to the conclusion that important opportunities were available, in which the expertise of the historians was a central asset. In the 2000s, I entered into a joint research project using neural networks on digital history with a historian that succeeded in producing results of mutual interest to me, the computer scientist, as well as to the historian. Computer science had caught up with history.

Today, the situation to some degree has been reversed, in that historians have started to seek out the advanced methodologies of computer science. Historians, like all researchers in the humanities and social sciences, wish to work in an analytically and methodologically solid manner. Occasionally, the success of natural sciences has led historians to find research questions where the borrowing of methods of natural sciences would be suitable and sufficient. This might be for wishes to achieve a wider generalisability and predictive power may be sought. However, in many cases, this leads to reductionism that prevents the results to be relevant within the complex world of humans as individuals and as social constellations. The challenges of how to account for symbol function, human intentionality and the role of artifacts are just some of the many factors that still render history a very challenging field for computer science. But the development within computational analysis, modelling and visualisation methods and tools are changing this situation, which is exemplified by the research in this volume.

The current research illustrates the state-of-the-art nature of this collaboration and when looking even further ahead there are new challenging opportunities related to history that stem from possible collaboration among history, other disciplines in humanities and computer science. From the point of view of cognitive linguistics, the meaning of meaning could be studied more carefully than what is usually done within the study of history. The meaning of linguistic expressions is dependent on the historical, societal and linguistic context in which they were written. Qualitative nuances can further be obtained by studying how items such as words, names, events, periods of time, individual persons or institutions are related to one other through some data than can be studied using statistical machine learning methods. These results can further be studied using the historian's expert considerations. Although

this line of research is already being conducted today, the studies are usually limited by focusing on time series or so-called matrix data.

If one would try to predict what the future might offer for the next generation of digital historians, one mathematical concept in particular could be considered relevant for historians, that of the *tensor*. In order to explain what a tensor is about, one can consider Excel spreadsheets. As a mathematical structure, a matrix is like an Excel spreadsheet. A kind of plate of numbers on a table. A tensor is an extension of this structure. In the case of a tensor, there are several layers on top of each other. For instance, in the traditional matrix ('on the table'), the number of people in the different neighbouring areas may be stored as numbers. In a tensor, layers of different years may be added so that the number of people in the different years can be conveniently stored and analysed. Tensors are essential extended data structures that could be highly useful in, for example, studying conceptual change in history, varieties of interpretations of the same word or item by different people, the development of some phenomenon over time within a complex context, or filling in gaps in history with hypothetical data to be searched for. This potential of the tensor remains for future historians and computer scientists to realise. Naturally, it is not the only promising direction from the methodological point of view.

The works in this collection provide a view on how history can be simultaneously studied with analytical rigour and without the need to straightforwardly accept the need of reductionism. The developments of studying human behaviour, culture and history with computational modelling, data science and complexity science and thus to engage with and better understand the new tools of our digital times is also a promise of an increasingly better ability and central societal role for history to help us understand our digital present and future.