McDONALD INSTITUTE CONVERSATIONS

Authenticity and cultural heritage in the age of 3D digital reproductions

Edited by Paola Di Giuseppantonio Di Franco, Fabrizio Galeazzi and Valentina Vassallo

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head dress

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with contributions from
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Mark Elliott, Kevin Garstki, Sorin Hermon, Stuart Jeffrey,
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Figures

Chapter 3

Digital authenticity and the London Charter

Sorin Hermon and Franco Niccolucci

The London Charter (http://www.londoncharter.org/) published almost a decade ago, set-up principles for the use of computer-based visualization methods and outcomes in the research and communication of cultural heritage. In particular, it aims at providing a benchmark having widespread recognition among the various communities of use, promote related intellectual and technical rigor, ensure that computer-based visualizations can be properly understood, used and evaluated in order to scientifically contribute to the study, interpretation and management of cultural heritage assets and ensure access and sustainability for such outcomes. One of the main concepts addressed by the principles of the Charter is intellectual transparency, i.e. the formal representation of the reasoning process generating a visualization outcome, along with the primary data used and its transformation process. Accountability and reproducibility are basic requirements in any scientific discipline; consequently, the Charter details how these should be addressed. In other words, the authenticity of a digital visualization outcome can be expressed as its ability to comply with the principles of the London Charter.

Computer-based visualization of cultural heritage has already a long history of use in social sciences and humanities (Chalmers et al. 1995, Forte & Siliotti 1997, Barceló, Forte and Sanders 2000, Goodrick & Gillings 2000). What has started more than a quarter of century ago as a proof-of-concept, i.e. computer-aided 3D visualization of excavations stratigraphy is a valid tool for investigating archaeological remains (Reilly 1992), developed in the next decades into elaborate educational tools, where 3D models are used for academic teaching (Sanders 1999, Taylor-Helms et al. 2013, Lackovic et al. 2015), platforms and means of public dissemination and communication of cultural heritage (Silberman 2004, Karp 2005, Bruno et al. 2010), distinct field documentation methods (Olson et al. 2013, Athanasiou et al. 2013, De Reu et al. 2014, Hermon, Iannone and Amico 2014, Remondino & Campana 2014, Berggren et al. 2015), research methods (Niccolucci & Hermon 2013, Hermon & Niccolucci 2015, Hermon 2008, Hermon, Niccolucci and D'Andrea 2005, Hermon & Fabian 2002) and proper research environments where computer-based visualization is employed to elucidate research questions about the past (Forte 2010, Smith et al. 2013, Gaugne et al. 2014, Knabb et al. 2014, Sanders 2014).

In parallel with the growing adoption of computer-based visualization in the cultural heritage domain, a demand for an increased 'authenticity' of the visualization, from a cultural heritage perspective, was put forward (Frischer et al. 2002, Bakker et al. 2003, Bentkowska-Kafel et al. 2012). Guiding concepts were 'transparency of reasoning' (Damnjanovic et al. 2013) and 'credibility of research' (see also Niccolucci & Hermon 2010) and how these can be formalized (Niccolucci & Hermon in press, Niccolucci et al. 2015), implemented and published, along with the digital visualization product itself. In other words, the research community of the late nineties and early twenty-first century became aware that there is a need for solid principles guiding such efforts if the visualization outcome is to be recognized as the product of a scientific process.

Either fundamental, applied or a combination of both, any scientific research starts with a question – described in its aims and the expected result. A hypothesis is thus formulated and data is collected. It goes without saying that the collection of data (method, amount and quality) must be aligned with the research aims and the advanced hypothesis. Data is then analysed and synthesized, in order to corroborate or reject the formulated hypothesis. Such a process may be repeated several times, until the research is satisfied with the results or these are consistent in all iterations. The final step of the process is the scientific publication, which according to its type, may or may not include raw data (seldom), highlights from the analysed data along with the processing method and, in most cases, a non-structured presentation of the reasoning process, which ultimately led to the published conclusions. Therefore, a basic requirement from any scientific publication, i.e. the ability to assess and evaluate the results published, is rarely fulfilled in its entirety.

The situation gets even more complex when the research involves computer-based visualization, in any or all of its stages – data collection, archiving, processing, deriving conclusions and publication. Such a research relies on digital data that either represents real features (an excavation area, artefacts, architecture components, etc.) or is the result of a digital (2D/3D) modelling process of assets with no, or partial correspondence in real life. In the first case, the authenticity of the digital surrogate representing an existing physical feature can be expressed (and quantified) in terms of accuracy the instrument involved in the data acquisition and its resolution, as well as the performance of the software involved in transforming a physical reading (laser-based, light-based or digital imaging being most common techniques) into a digital outcome (a point cloud). The same goes with an analogously captured data and later on digitized. The results depend on the accuracy of the data capture method and the transformation from analogue to digital. In the second case, where the digital data is the result of a reasoning process, the assessment of data quality is more complex (Hermon et al. 2006).

In the above-mentioned cases, the quality of data (usually a 3D point cloud) is expressed as the goodness-of-fit between the physical object and the digital one, i.e. how well the digital surrogate represents the physical reality. However, such replication is very limited in its nature, a digital surrogate being often limited to geometry features, some colour (light) properties and rarely material properties (elasticity, strength, toughness, acoustical, mechanical, and so on). In reality, there is no protocol defining a set of measurements and observation that can quantify the goodness-of-fit between a physical object and its digital surrogate. The short paragraph above described in more detail the complexity of the relationship between data acquisition, the physical assets (or the concept) analysed and its digital surrogate. It also exemplifies the need for intellectual accountability and transparency of research, elemental components in any discussion about authenticity. The same complexities exist for the other components of research – archiving, processing and drawing conclusions. And this is precisely why the London Charter has been written – to propose a set of principles to be followed by researchers, educators, curators and alike, who wish to employ computer-based visualization in the research and communication of Cultural Heritage.

The London Charter – preamble and current situation

The London Charter for the Computer-based Visualisation of Cultural Heritage was conceived in 2006, with the aim to provide a set of principle that would ensure the needed methodological rigour in cases when computer-based visualization is employed in the research and communication of cultural heritage. At that time, it was also important to provide a set of solid and long-lasting principles that would further promote such use of computer-based visualization in the domain of Cultural Heritage, while in the same time offering a sustainable solution to the issue of 'intellectual transparency' (Beacham et al. 2006). Moreover, such principles would have strengthened the professional norms of the newly emerging field as a research domain, particularly in terms of argument and evidence (Denard 2012, 2013). Since its initial publication in English, the Charter was translated and published in Italian, Spanish, German, Hungarian, Portuguese, Bosnian, Japanese, Chinese and Farsi, while Russian, French and Greek translations are currently undergoing a final editing process (http://www.londoncharter.org/). Its objectives are:

- Provide a benchmark having widespread recognition among stakeholders.
- Promote intellectual and technical rigour in such uses.
- Ensure that computer-based visualization processes and outcomes can be properly understood and evaluated by users.
- Enable computer-based visualization authoritatively to contribute to the study, interpretation and management of cultural heritage assets.
- Ensure access and sustainability strategies are determined and applied.
- Offer a robust foundation upon which communities of practice can build detailed London Charter Implementation Guidelines.

The first version of the London Charter was published in March 2006, following an international symposium (23–24 February) on 'Making 3D Visual Research Outcomes Transparent', convened at The British Academy, London, UK and hosted by AHRC 'Making Space' Project, King's Visualisation Lab, and co-sponsored and organized by the AHRC ICT Methods Network and VAST-Lab, PIN, Prato, Italy, in the framework of the EU funded project EPOCH Network of Excellence and its standards activity. The next day, an experts seminar was convened at King's College London, during which the main principles of 'The London Charter for the Use of Three-dimensional Visualisation in the Research and Communication of Cultural Heritage', version 1.1, were established and a month later published online and through various scientific articles. A second version (2.1) was published three years later, capturing the debates and discussions triggered by version 1.1 (Niccolucci et al. 2010). A major development was the inclusion of other forms of digital visualization, '… embracing 2D, 3D, 4D and even hard-copy printouts or computer-generated physical objects such as replicas of museum artefacts…' (Denard 2012, 61). Thus, the London Charter became 'The London Charter for the Computer-based Visualisation of Cultural Heritage' and is currently the latest version available. Since its publication, The Charter's principles are applied in computer-based visualization projects around the globe (Lake 2012), some explicitly mentioning it (Hermon et al. 2007, Georgiou & Hermon 2011, Murteira & Rodrigues 2016), others implicitly relying on its principles (Gea at al. 2013).

The next paragraphs will details its principles and how these were applied to a visualization project, having dual scope of research and communication of Cultural Heritage.

The London Charter principles

The Charter is built around six fundamental principles that, if followed and implemented, they will assure the needed data transparency, intellectual accountability and re-usability of visualization outcomes, while in the same time these principles are the backbone for evaluating the authenticity of a visualization product, where authenticity is referred to as the ability to scientifically evaluate and assess a visualization outcome, be it digital or physical. The following paragraphs details these principles and how they were addressed in a research project where digital (2D and 3D) visualization played a fundamental role.

Description of the case study

The uniquely shaped octagonal domed church of the Christ Antiphonitis (Fig. 3.1) in the district of Kyrenia (Cyprus) was built in the twelfth century and decorated with frescoes along its interior walls. A new layer of frescoes was applied in the fifteenth to sixteenth centuries; two of these are exceptional for their artistic and historic value: the story of the Tree of Jesse (a pictorial genealogy of the Virgin) located on the southern wall of the octagon, and the Last Judgment, on the northern wall. Following the Turkish military invasion of Cyprus in 1974, looters stripped off big portions of its pictorial decoration and extracted them from the island, in order to be sold abroad. Since the end of the 1990s, due to efforts of Cypriot authorities, more than 70 fragments

Figure 3.1. *The church from outside.*

Figure 3.2. *Some of the repatriated frescoes.*

of its frescoes returned from USA and Europe to the Byzantine Museum of Nicosia (Fig. 3.2), where they are currently under conservation and restoration for future display. These were digitally documented using high-resolution ortophotos. The inner space of the church was documented by similar means, in order to virtually re-position the frescoes in their original locations. The virtual re-composition of the frescoes along the looted walls helped quantifying the missing parts, correctly re-locate virtually each fragment at its original position, obtain accurate colour information and prepare a digital musealization product, to be included in the permanent exhibition display at the museum (Abate et al. 2016).

Principle 1. Implementation. *The principles of the London Charter are valid wherever computer-based visualization is applied to the research or dissemination of cultural heritage.*

Since our project involves both research and dissemination, it is important to clearly define the implementation guidelines for each path. The research component includes guidelines on how the entire scientific process is to be documented. CIDOC-CRM is instrumental here, being an ontology developed to provide definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation (Doërr 2003). Particularly relevant here is the extension CRMdig, defined in order to capture information on the creation of digital data (Theodoridou et al. 2010, Pitzalis et al. 2010). Consequently, such information was described through a metadata schema developed in our research group (Ronzino et al. 2012), which is based on the CARARE 2.0 metadata schema (D'Andrea & Fernie 2013). Such data is stored and online accessible through a repository of scientific data produced by our research group (Kolosova & Hermon 2013). The second aspect of our case study, dissemination, followed recommendations proposed by the V-MUST project on Virtual Museums (Hermon & Hazan 2013). They include, among others, a clear description of the target group and adaptation of content to such a group, an analysis of the exhibition environment, level of interactivity desired for such a type of dissemination product, degree of immersion and level of engagement of visitors.

Principle 2. Aims and methods*. A computer-based visualization method should normally be used only when it is the most appropriate available method for that purpose.*

The main aim of the research component of the project was to recompose the scenes of the two frescoes described above. Such a reconstruction is essential in assessing how much is still missing from each scene and how much is totally destroyed and irrecoverable; furthermore, once the virtual re-composition is completed, the interior of the church can be analysed in terms of visibility of the scenes from various angles and perspectives, illumination of each scene and relation with each other. Over 70 fragments, of various sizes and shapes were repatriated, in various preservation

Figure 3.3. *Documenting the fresco fragments.*

conditions. Since there were no accurate plans of the church and the only documentation available were black and white photos taken prior the desecration of the church, a first step of the re-composition process was to create a digital environment where the digital surrogates of the frescoes fragments can be relocated. Therefore, each fragment was photographed and ortophotos were created (Fig. 3.3). These ortophotos had to be positioned along the two walls of the interior of the church (north and south). Given the restriction of scientifically operating in the occupied area of Cyprus, the only way to capture the interior geometry of the church was by means of photogrammetry, which produced a dense point cloud (Fig. 3.4) upon which the ortophotos could be positioned.

Since the frescoes were removed in an unsupervised manner and were later cut in order to maximize the selling of separate pieces, they display different erosion patterns along their edges; moreover, the pictorial layer is damaged in many cases. Therefore, any attempt at automatic matching would have failed from the start. Therefore, the selected method was the creation of a 3D model of each interior wall, adding as texture the old black and white documentation photos, align them with the photos depicting the nowadays situation and, based on the above, align the ortophotos of the frescoes fragments (Figs. 3.5 & 3.6). Further assessments were done to evaluate the extent of missing frescoes (Fig. 3.7) and the overall extension of each scene.

Figure 3.4. *3D point cloud of the interior.*

Figure 3.5. *Last judgement scene (northern wall). 36 fragments were virtually re-located, which is 72 per cent of the scene.*

Figure 3.6. *Tree of Jesse scene (southern wall). 32 fragments were virtually re-located, which is 77 per cent of the scene.*

Principle 3. Research sources*. In order to ensure the intellectual integrity of computer-based visualization methods and outcomes, relevant research sources should be identified and evaluated in a structured and documented way.*

The research sources employed in the visualization of the interior of the Antiphonitis church are a set of historic photos (black & white) taken prior its desecration, which served as a basis for the virtual re-positioning of the digital models of the repatriated fragments. All the other data has been collected by the authors of the research, i.e. sets of images of each fresco fragment and a set of images from capturing the interior of the church (Abate et al. 2016).

Principle 4. Documentation*. Sufficient information should be documented and disseminated to allow computer-based visualization methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.*

The visualization elements used in the research are ortophotos of each fresco fragment and the 3D model of the interior of the church, needed in order to obtain accurate architectural details of northern and southern walls of the octagon, to later serve as reference frameworks for the re-composition of the frescoes fragments. The delineated area was documented using the Structure from Motion (SfM) approach. Photogrammetric rules were followed as much as possible, given the environment and operating conditions. The interested area was subdivided in blocks, which were documented separately by a set of images, using the same camera and same settings. Some 700 pictures were acquired from the ground level, in raw image format. The camera used, mounted on a tripod, is a Canon 600D with a 18-megapixel CMOS sensor (4.3 μm pixel size) with a Canon EF 20 mm 1:2.8 prime lens.

The ground sample distance (GSD) was calculated in ~1 mm at an average camera-object distance of 5 m, with an image scale of 1/250. Ground truth measurements were taken in order to scale the model. The image acquisition was performed without a proper light setup, in an environment with changing luminosity, during the opening hours of the site (10 am – 2 pm), when natural daylight illuminates the interior. The only possible shrewdness was to turn off the yellowish lights emitted by the chandelier hanging from the vault ceilings. A standardized colour chart was used for each image sequence. The masking procedure of

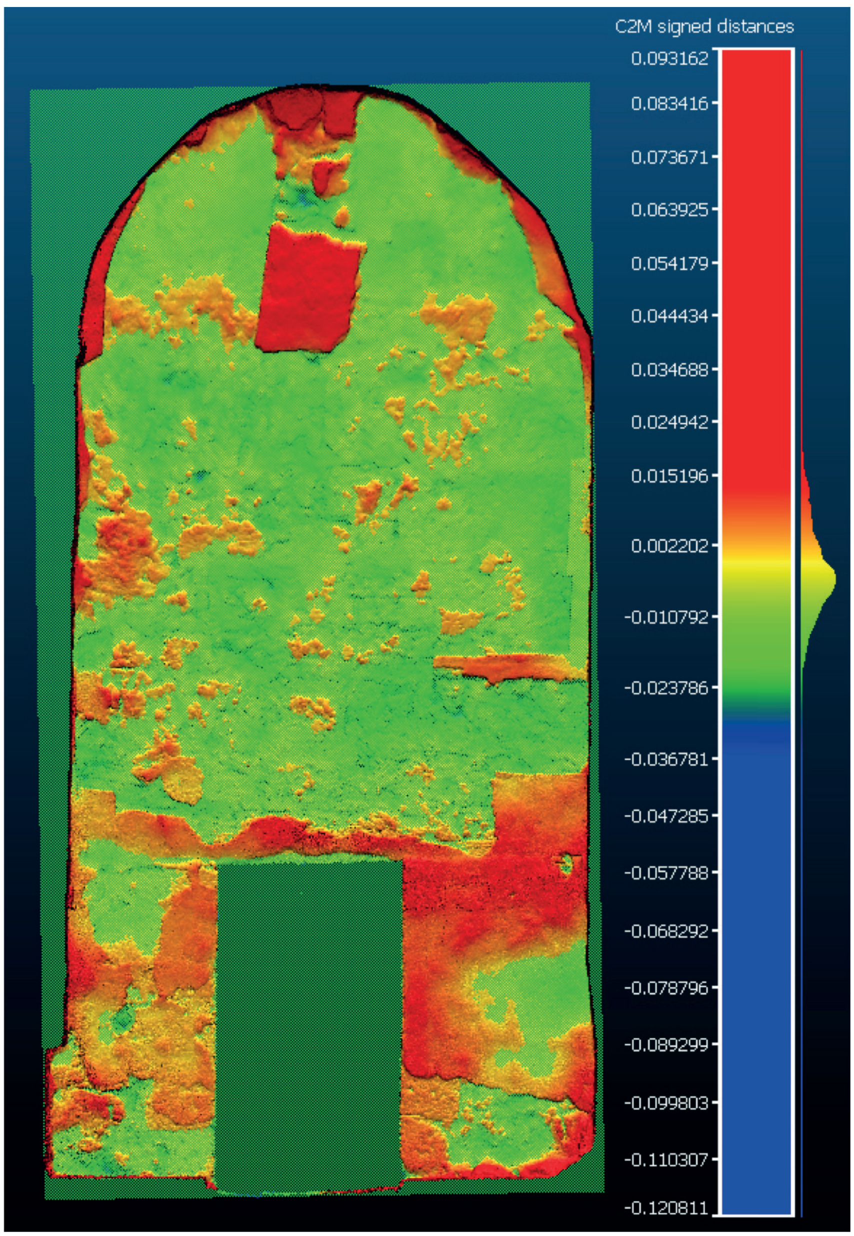

Figure 3.7. *Last Judgement scene wall. Red areas correspond to preserved in-situ frescoes, green ones to areas where frescoes are missing (Abate et al. 2016).*

the wall dataset was particularly time-consuming, due to the presence of light spots that occurred during the photos shooting because of the uncontrolled light environment (Abate et al. 2016). The extracted dense point cloud consists of ~255 mil points, with an average spatial resolution of 0.6 mm, obtained by applying a high redundancy and image overlapping.

The frescoes fragments were digitized *in situ* at the museum and processed using the Agisoft Photoscan software. Each photo was pre-processed to according to a colour checkerboard in order to equalize its colours, and the background has been masked to facilitate and improve the quality of the alignment process. The extracted tie points were filtered out in order to limit their image re-projection errors below 0.5 pixel and to keep only well distributed and reliable points. A dense point cloud, a mesh 3D model and orthophotos with an average pixel dimension of 0.4 mm were created for each fresco fragment. Some fragments were still covered by tissues for conservation purposes; their digital images were pre-processed with a photo editing software in order to improve their colour information (i.e. white balance, colours enhancing, etc.). All orthophotos were imported into AutoCAD for a correct alignment within a unique reference system. After the photogrammetric process all images were properly scaled and no further adjustment was necessary.

Before the final alignment of all fragments into a single 3D reference system, the current condition of both walls, originally fully covered by frescoes, was assessed. The dense point clouds of the two walls were analysed using the CloudCompare open source software (Cloud to Mesh distance tool). For each point cloud, a best fitting plane was first extracted and used as reference, resulting in a mean plane fitting RMS of ~ 0.015 m. After the calculation of the distances between each point cloud and its best-fitted plane, the resulted scalar field visualization tool highlighted the parts of the wall where frescoes survived (red areas) and the damaged surface of the wall from where frescoes were ripped off (green areas) (Fig. 3.7).

Starting from the best fitting plane results, a quantitative analysis of the walls area, calculated in square metres, was performed in AutoCAD. The assessment was made on orthophotos with and without the fragments' virtual re-location. The Tree of Jesse wall extends over ~15.7 sq. m. The looted area is *c*. ~7.20 sq. m, or *c*. 45 per cent of the original wall. The recovered fragments represent an average surface of 3.65 sq. m, thus reducing the missing frescoes to 23 per cent. The Last Judgment scene extends over an area of ~17 sq. m. This area showed a percentage of missing frescoes close to 75 per cent (12.8 sq. m). After the repositioning of the 36 fragments, the missing surface decreased to *c*. 28 per cent, equivalent of 4.75 sq. m. Some *c*. 3–5 per cent of the frescoes on each wall were totally destroyed during their looting.

Principle 5. Sustainability*. Strategies should be planned and implemented to ensure the long-term sustainability of cultural heritage-related computer-based visualization outcomes and documentation, in order to avoid loss of this growing part of human intellectual, social, economic and cultural heritage.*

All data produced is on standard formats, readable with a wide range of software. 3D models and digital images used are stored in an online accessible repository, together with their descriptive metadata (Ronzino, et al. 2012), which contains both machine-generated information (technical details on how data was obtained) as well as what in the relevant literature is called 'paradata' (how data was obtained) (Baker 2012).

Principle 6. Accessibility*. The creation and dissemination of computer-based visualization should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage.*

The entire data generated by the project is made available in its raw and processed formats, along with related metadata and paradata (see above).

Summary and conclusions

'Authenticity' is not a term employed or directly addressed by The London Charter, possibly because the term 'authentic' is in fact a bit misleading. It may sound as defining an object as the real, and only one, undisputed thing, opposed to a fake, a copy or a counterfeited substitute. Indeed, many digital replicas are so: they do no represent faithfully the original. Compliance with The London Charter guarantees instead that they are 'authentic' copies, i.e. they are accurate and reliable, based on facts, and such facts are reported to guarantee the intellectual accountability of the scientific research that led to produce the digital artefact, and data transparency. The London Charter principles were defined precisely in order to assure that these two components are addressed whenever computer-based visualization is applied in cultural heritage research. As such, the quality of a visualization outcome can be measured quantitatively, (number of pixels, density of point clouds, number of scans taken, environmental conditions, etc.) where the threshold between authentic or not can be decided by each researcher according to its own acceptance level. Actually, such precision does not influence 'authenticity' as long as it is clearly reported and documented: what is 'authentic' for communication purposes may not be such when scientific analysis is involved. A description of how the creation process of a 3D model can be fully documented with CIDOC CRM can be found in (Amico et al. 2013).

Complying with The London Charter provides the information necessary to any future researcher to assess if the involved digital object is 'authentic enough' for its intended re-use. This aspect is even more important when the digital object does not correspond to any real object, but just depicts the supposed shape and appearance a real object had in the past. This is the case, for example, of virtual restoration, where fragments are recombined to digitally reconstruct the broken original. If often pieces recombine easily to fit well with each other, for other parts the assembly is based on computations or is inferred basing on other criteria, which need to be precisely stated (Hermon et al. 2011, Iannone et al. 2011).

Even more difficult is the documentation of the virtual reconstruction of buildings, monuments and sites. To avoid that the reconstruction is a mere result of imagination, there are many implicit decisions that need to be made explicit and accurately documented, in the same way as the meaning of a corrupt text is patiently reconstructed through a philological approach (Frischer et al. 2002). In both cases, the result will not 'authentic' in a strict sense – and it could not be: the original does not exist – but will be so at the best of one's knowledge.

The London Charter concerns the shape and appearance of objects, which do not exhaust the features of objects. There are many others, either directly perceivable (the touch and feel, for example) or hidden ones (the chemical composition), which probably will need to be addressed with the same approach. For most of the archaeological science analyses, for example, there are so far no similar guidelines, and the 'authenticity' of the result relies only on generic research good practices. Thus, as far as authenticity is concerned, there is a risk that scientific analyses are no less deceptive than a pretty, but undocumented, visualization.

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