Muz., 2018(59): 54-62
Rocznik, eISSN 2391-4815
received – 03.2018
reviewed – 04.2018
accepted – 04.2018
DOI: 10.5604/01.3001.0012.0619

REFLECTANCE TRANSFORMATION IMAGING. ABOUT A PHOTOGRAPHIC METHOD FOR THE DOCUMENTATION AND ANALYSIS OF MONUMENTS

Paweł Lech Polkowski
Archaeological Museum in Poznań

Piotr Witkowski
Institute of Archaeology, University of Warsaw

Abstract: Modern technology has been offering an increasing number of tools for the digitalisation of monuments or works of art. 3D visualisations, which allow obtaining a very realistic image of the subject, are particularly popular. However, for many culture and science institutions, including museums, such tools can be unavailable, primarily for financial reasons. The Reflectance Transformation Imaging (further as: RTI) method, discussed in this article, appears to be a solution, which – being relatively inexpensive – offers a wide range of possibilities regarding the documentation of monuments by allowing – without the need to resort to high-tech equipment – to create 2.5D images out of regular digital photographs. The article offers a brief characteristic of the way in which the RTI method works, at the same time presenting successive stages in the procedure of obtaining images. In order to illustrate the results of this method the authors referred to their experiences with RTI Imaging; with this purpose in mind they described RTI images of three stones with petroglyphs featured at the Archaeological Museum in Poznań. Upon the basis of their achievements and pertinent literature they presented their assessment of the RTI method, indicating both its positive and negative aspects.

Keywords: Reflectance Transformation Imaging method – RTI, photographic documentation, iconography, digitalisation, multimedia.

At present digital photography constitutes a foundation for a wide group of myriad methods and techniques applied for the purpose of documenting archaeological sites, monuments, and museum exhibits. The usage of the majority of those methods and techniques (i.a. multispectral imaging, photogrammetry, scanning) is often associated with considerable financial input. This is why it is worth seeking ways that are not very costly and, at the same time, offer analytical possibilities greater than those of traditional photography. One such method is Reflectance Transformation Imaging (further as: RTI), which makes it possible to create an interactive digital model of the surface of an actual object or its part. Such interactivity consists of the option of a virtual illumination of the received model from all possible directions. Lights and shadows created on the surface of the model are the outcome both of differentiated topography and other material properties of the documented object.[1]

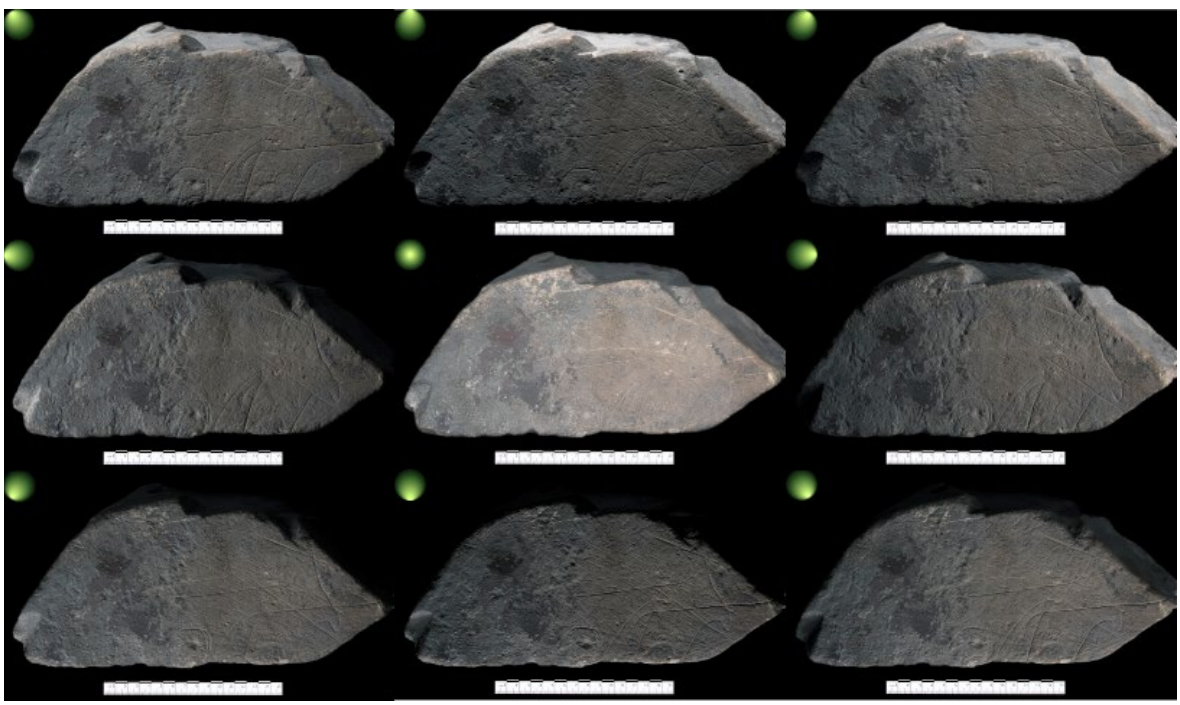
Description of the RTI method

RTI is a computational method based on digital photographs. The making of a model calls for a minimal set of about 24 photographs taken with a camera placed in one place during the session. The location and orientation of the documented object also remain unchanged. The camera lens should be perpendicular to the surface and the camera is switched to a manual mode. After determining suitable parameters of exposure (shutter speed, aperture diameter and sensitivity) and focusing (for all documented surfaces) we block the last function and leave the exposition parameters unchanged in the course of taking all the photographs. The camera is stabilised on a tripod and remote control will be guaranteed by a computer or a telephone (tablet) application. This will prevent predominantly the undesired motion of the camera in the course of the session.[2]

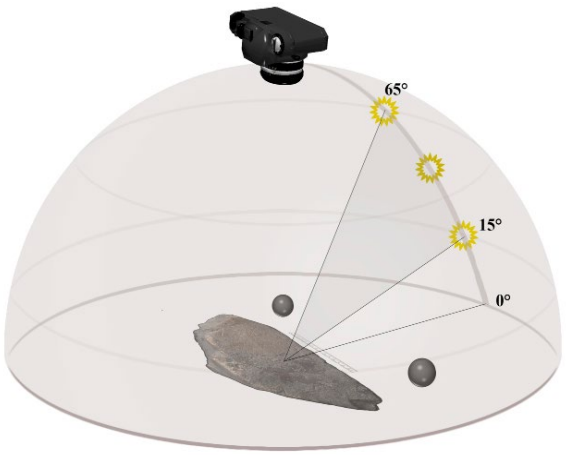
In the frame we place the historical monument together with a measuring device (for the purpose of a later estimation of particular features of the monument's surface), a colour chart (in order to calibrate colours registered in the photographs) and two shiny calibration spheres thanks to which each photograph will register light reflections produced by the flash. We shift the lamp prior to taking each successive photograph so that all the points of the location of the source of light could be arranged during the given session evenly around the object. The distance between the lamp and the centre of the monument should be constant and no smaller than twice-thrice its diameter; light should be cast at an angle of 15°–65°.

The constant distance between the map and the monuments is the reason why photographs document changes of the colour of the surface, which reveal themselves when light falls on an object from assorted angles. Such changes additionally depend on the topography of the surface and the properties of the material out of which the object was made. Since we document their impact upon light (in the form of a phenomenon known as reflectance) information about those features of the monuments might be discovered in the course of a later analysis of the digital model.[3] It is worth adding that numerous museums and university units applying RTI built special light mooting in the form of domes or arms with affixed sources of light. Such appliances considerably accelerate and facilitate measurement, i.e. the acquisition of photographs.[4]

After the completion of the entire set of photographs we are obliged to assess their quality and usefulness in a further



1. Comparison of the visibility of individual surface features of the monument (stone no. 1), RTI screen capture in the *Default* mode of visualisation depending on the direction from which the object is illuminated; green sphere informs about the direction of the illumination



2. Synthetic presentation of a photography session during the first stage of using Reflectance Transformation Imaging

3. Photography session at the Archaeological Museum in Poznań

phase of imaging. The focus and definition of the photographs are appraised together with their contents. Next, we remove from the collection those photographs, which had been taken incorrectly or which registered undesired elements, e.g. our shadow cast on the surface of the monument. If after their removal the set becomes diminished or, if as a consequence of an assessment, we arrive at the conclusion that the camera moved during the session, then the latter must be repeated.[5]

The successive stage is the aggregation of data and the creation of the RTI image. With this purpose in mind we should remove from the photographs distortions and aberrations caused by the lens and the camera and save transposed photographs in the JPG format. We then access those folders in a specialist RTIBuilder programme, which is semi-automatic. Having indicated parts of the frame in which we placed the calibration spheres the programme determines the direction of the source of light for each photograph. We can correct the results of this process if such a need arises. In the last step of this stage the program generates RTI folders containing a model of the documented object.[6]

The digital image of the monument can be viewed in one of the dedicated viewers (RTIViewer,[7] CherOb,[8] ISFStandaloneViewer[9]), choosing one of several implemented modes visualising the object as well as the direction from which we shall illuminate our model virtually (see: fig. 1). Virtual manipulation with chiaroscuro on the surface of the depicted object realistically imitates the process of experiencing a genuine monument and, at the same time, offers an extremely effective tool for analysing the properties of the surface. The only mode that does not offer interactivity is so-called normal mapping – an image in which the colour of every pixel was defined by the direction of an inclination of a fragment of the monument's surface represented by this pixel.[10]

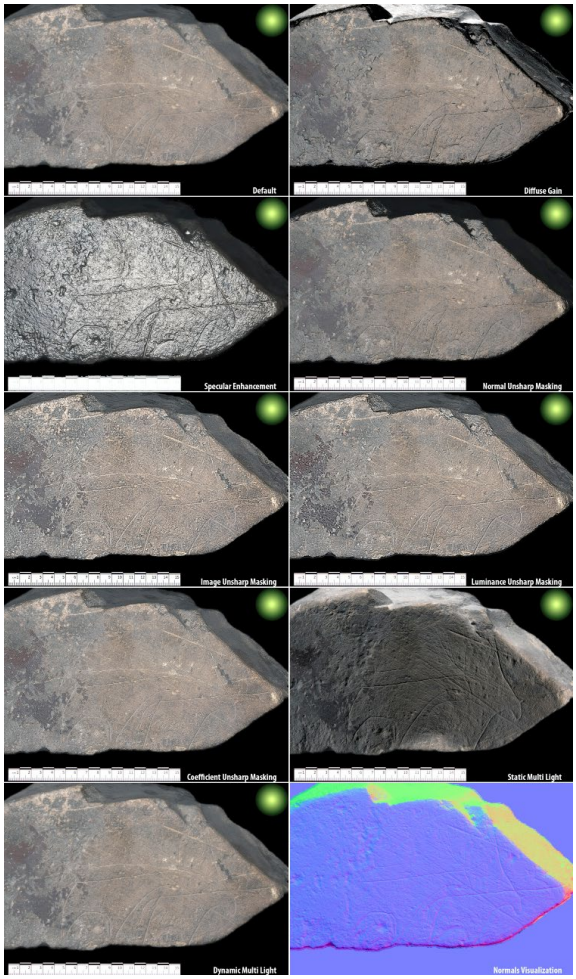
What purposes does RTI serve?

RTI offers us a visualisation of monuments, which, albeit not three-dimensional is, for all practical purposes, not greatly inferior. RTI images permit us to map the surface of assorted objects extremely precisely, and the information that we shall seek is partially dependent on the type of objects and the traces that we can observe on them.

The first and probably the most universal category of analyses using RTI is studying iconography. A controlled simulation of illuminating the surface of an object, causing changes of light and shadows, makes it feasible to discover details invisible even with the naked eye or simply difficult to notice. It is not surprising, therefore, that this analysis of RTI images is one of fundamental ways of using the method in archaeology or museology, and that the most often studied categories of monuments are rock art and graffiti, bas-reliefs, inscriptions on stone and timber, clay seals or their imprints on papyrus, parchment or paper, as well as coins, bones, and paintings.[11]

The second group of analyses to which RTI images are subjected is connected with an identification of traces of tools.[12] An interactive change of lighting makes it possible to describe the manner of modifying the surface (a removal of its fragment or an imposition of different material), and thus allows to draw conclusions about the sort of tool or technique used for creating the object. Consequently, we achieve insight into the workshop of the author and the history of the functioning of the object in successive cultural contexts. After all, traces of instruments do not have to refer solely to the emergence of a given work.

Yet another application of RTI involves studying the current state of the preservation of a monument and discovering the damage incurred to the surface. For this purpose, we need two RTI images: a referential image prior



4. Comparison of RTI visualisation modes available in the RTIViewer program. The object of imaging is a stone with petroglyphs (no. 1) found in the vicinity of the Fourth Cataract in Sudan, 3000–2000 B.C.

to the changes and an image created some time later and documenting the damage (if the latter took place). The study also consists of comparing both models and appraising the observed changes. Just as in the case of iconographic analysis so here too RTI images enable us to discover elements indiscernible with the naked eye.[13]

In view of the fact that the RTI image is also an excellent instrument for presenting exhibits the described method serves not only documentary or analytical purposes. Collections of digital models can be also helpful for expanding the offer made by galleries and museums in their Internet services. The interactive manner of presenting contents makes it possible for visitors to make their own discoveries, since they have a chance for more detailed observation either at the museum or at home. It must be kept in mind, however, that RTI images should be more of an addition to an exhibition and their purpose is not to replace the original monuments. We perceive their assets rather in the educational dimension and in the fact that they could encourage to directly experience the actual exhibits.

The spectrum of RTI application is, therefore, vast and will probably expand even more as the method continues to develop. Indubitably, this is a tool that could be universally used especially in all sorts of institutions dealing with cultural legacy. In order to present the practical assets of the method and emphasise its weaker and stronger sides we would like to demonstrate our experiences with RTI within the museum context.

RTI images of stones featuring rock art at the Archaeological Museum in Poznań

The Archaeological Museum in Poznań houses nine stones with petroglyphs obtained in the course of excavations conducted in the vicinity of the Fourth Cataract of the Nile in Sudan.[14] Although their iconography is relatively well recognized they still contain numerous elements, both iconographic and others, whose identification is unobvious or unclear. For the purpose of testing the RTI method we chose three stones (inv. no. MAP 2010:85/1, 2010:88/1, 2010:88/2). Below, we would like to characterise briefly the outcome of our work, accentuating that a copious presentation both of the process of creating the imaging and its analysis is being prepared.

The stones feature predominantly likenesses of cattle (see: fig. 1, 4–7), albeit executed in different techniques. The style of the depictions allows us to include them in the so-called Kerma horizon, i.e. the third and second millennium B.C. Stone no. 1 (see: fig. 1, 4–6) was covered with two petroglyphs of long-horned cattle. The same is true of stone no. 2 (see: fig. 7), which shows two cows and an anthropomorphic figure situated above them. Only stone no. 3 (see: fig. 8 and 9) poses an identification puzzle by defying interpretations due to its abstract form and damages.

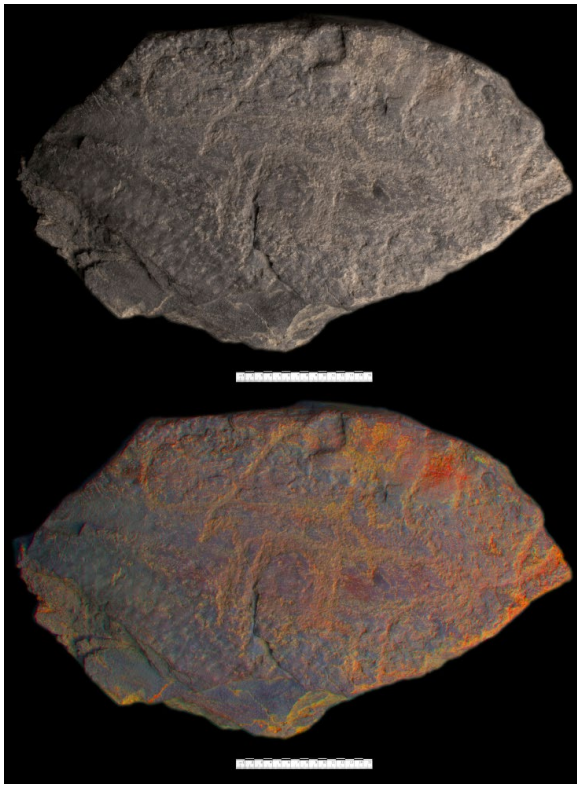
The stones selected by us differ owing to the properties of their surfaces and petroglyphs. The surface of stone 1. is relatively smooth and hence the depictions distinctly stand out from the background, but in the case of the remaining stones the petroglyphs are less legible as a result of an irregular and, at times, rough surface. Techniques used for creating particular petroglyphs also differ. Depictions on stones 2. and 3. were executed in the picket technique and thus were produced by striking the stone with a hard tool. Petroglyphs on stone 1. were carved with a very sharp tool, as evidenced by an extremely thin contour line. All those (and other) differences affect the way in which the stone surface reflects light; hence we expected various results of RTI imaging.

The stones were photographed with a Canon EOS 750D camera and a Canon 60 mm f/2.8 EF-S Macro USM lens, while using a tripod. The monuments were illuminated with Fomei Ring Flash Panther 600 mini and Quadralite Reporter 360, combined with a navigator. The entire session was conducted by using the EOS Utility programme, and after completing a series of photographs of each stone they were transposed by applying the Adobe Photoshop and RTI Builder programmes.

The prime goal of creating the images was to obtain documentation that would offer much better quality than the one executed with traditional methods (drawing, photography) and which would increase the possibility of presenting the stones within a museum context in view of the fact that visitors may find the discussed petroglyphs insufficiently visible. Although we did not anticipate that

5. Stone No. 1, RTI screen capture in the *Image Unsharp Masking* mode of visualisation

6. Close-up of an unfinished (?) petroglyph of a cow (?) on stone no. 1, RTI screen capture in the *Diffuse Gain* mode of visualisation



7. Stone No. 2, RTI screen captures in the normal version, and with the colour enhancement function used in the *Default* mode of visualisation

8. Stone No. 3, RTI screen capture in the *Diffuse Gain* mode of visualisation, illuminated from different angles

RTI images would also allow us to discover new motifs on stone surfaces we did not exclude such a possibility.

In the case of all three stones we managed to create imaging whose level of detailed presentation is much greater than that of the documentation we had at our disposal until then.

In other words, RTI fulfilled expectations as regards the quality of documentation. RTI images of stones 2. and 3. allow a much more reliable description of the depictions and their natural stratification relations (stone 2.). In the case of stone 1., which, it was suspected, could contain additional engravings barely seen with the naked eye we managed to confirm the existence of at least one, possibly unfinished, depiction of a cow. Only the application of a suitable visualisation mode made the contours of this petroglyph visible. Although its identification as an animal remains debatable the existence of those engraved lines is clearly distinct thanks to RTI.

RTI also helped to verify the character of numerous traces on stone surfaces, which until then remained uncertain. In the case of stone 1. these were numerous engraved parallel lines whose full course could be observed only in the RTI image (they are seen with the naked eye but only fragmentarily). Stone 3., in turn, displays elongated lines, the result of friction (?) and certainly later than the petroglyph. Furthermore, analyses of RTI images make it possible to distinguish variances in coloured traces on this stone more fully, suggesting that perhaps we are dealing with traces executed with two different tools (see: fig. 9).

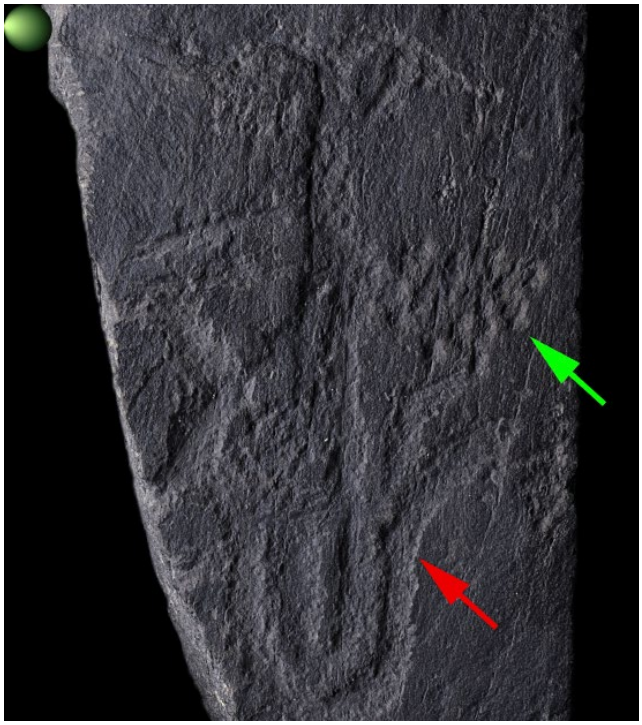
Without doubt, control over virtual light cast on stone surfaces permits extremely detailed analyses of their selected fragments. In all instances we obtained dynamic images, in which it is much easier to perceive depictions than in natural or museums conditions. Our expectations were not met only in the case of stone 2. because the anthropomorphic figure was still rather difficult to see. We thus decided to apply the colour enhancement technique in all the photographs of this monument (using the ImageJ[15] programme and DStretch[16] image enhancement), and then to once again create the RTI image by deploying these transposed photographs. Consequently, we achieved visualisation with an artificial colour composition but with perfectly visible petroglyphs.

The most important accomplishment of the entire experiment was the fact that we managed to obtain data that can be further transformed and analysed by using filters of other programmes. In this manner the documentation is not "final" and can be studied from the angle of seeking highly diverse information about examined objects. Our aim will, therefore, involve, i.a. further analysis of the stone, which, in our opinion, preserves traces of an earlier (?) petroglyph. Successive visualisations will assist identifying traces, which in the initial stage of analysis appear to be somewhat ambiguous.

We also notice the great potential of the imaging created by us in its further integration with the undertakings of the Archaeological Museum in Poznań. One of the ideas that we shall want to realise is placing RTI images on the Museum's website. Hopefully, accessing them will have a positive impact on interest in African archaeology and will simultaneously offer Internet users a feeling of greater involvement in experiencing historical monuments.

Assessment of the RTI method

The assessment of the RTI method presented in this article is certainly subjective, although taking into consideration



9. Close-up of stone no. 3 showing different sizes of colored traces (green arrow - big traces; red arrow - smaller ones) and elongated scratch marks created already after the execution of the petroglyph; RTI screen capture in the Image Unsharp Masking mode of visualisation

(Fot. 1, 2, 4-8 – oprac. P. Witkowski; 3 – P.L. Polkowski; 9 – oprac. P.L. Polkowski, P. Witkowski)

growing interest in its use, expressed by various institutions all over the world, the evaluation of RTI is, as a rule, positive. Our experiences of applying the RTI method incline us to underline the fact that despite the existence of certain faults and limitations the method possesses many more merits. They include, predominantly:

- **precision** – the obtained virtual model of the monument contains information about the shape of the object, the colour of its surface, its properties and current state, and, at the same time, is more precise than an individual photograph;
- **independence** – the process of documentation is much more objectivised, especially in comparison with drawn documentation of monuments and traditional digital photography highly dependent (especially in the course of field work) on existing light conditions;
- **non-invasiveness** – the RTI method does not require persons working on the documentation to touch the surface of the object, and thus minimalizes the risk of damaging the monument;
- **usefulness** – the resultant model helps, first and foremost, to reveal information barely perceptible or outright invisible to the naked eye within the range of iconography, traces of tools used during the process of creation, and techniques applied at the time, as well as natural changes occurring within the historical substance;
- **verifiability** – conclusions drawn from studies on RTI images can be relatively easily assessed thanks to the possibility of accessing RTI images to other scientists;
- **accessibility** – this is a relatively inexpensive method to apply: today, numerous necessary tools are part of the equipment used by the majority of museums and archaeological expeditions; the accessibility of the method is also discernible in its reasonably easy operation, which does not call for specialist schooling;
- **attractiveness** – the RTI image is also a visually attractive product, which may be used in a museum as an element supplementing expositions, and on a website, which, in turn, can have a positive impact on activity promoting museum events and collections.

Reflective transformation imaging is, however, not an ideal method and it is worth becoming aware of its faults:

- the fundamental problem involves the limited sizes of documented objects; imaging an excessively large surface causes the loss of topographic details and hence difficulties or the impossibility of carrying out credible meticulous analyses; moreover, very large objects call for more sophisticated procedures in the course of photograph acquisition – a tripod aimed at a monument ceases to be a good solution;
- the next limitation is the very process of creating the RTI file and, more exactly, the stage of the acquisition of images; measurements in the form of a photograph comprise the foundation of modelling and thus their execution should be technically correct and their characteristic gestures should include focus and the lowest possible image noise, which depends on the skill of the photographer, the quality of the equipment, and external factors;
- despite the fact that RTI images contain information about the colour and shape of the surface they still remain only two-dimensional (described more exactly as 2D + or 2.5D) and deprived of direct information about the location of particular surface fragments along axis Z; they thus lack a third dimension, which characterises 3D models and their distinctive features include limitation to a single point of view (the absence of a possibility of turning the resultant model around)
- although it is difficult to regard this as a fault it should be kept in mind that imaging objects with the RTI technique

is not fully objective; in other words, the RTI result always depends on the operator and hence images of the same object, obtained by assorted persons within separate documentation processes, will contain potential differences; this holds true in particular for methods involving a handheld flash, when it is difficult to keep ideally equal distances between the lamp and the object; whenever a frame or a dome is used differences of the obtained results will be probably much smaller.

Summing up, the RTI method has a great chance to become one of the most universally used instruments for the digitalisation of collections in institutions associated with cultural heritage. In an era of creating electronic databases, the transference of expositions from showrooms to websites, and omnipresent computer analyses RTI offers a great deal with relatively low financial inputs. The fact that it does not have to be applied exclusively by specialists dealing with informatics or photographers/graphic artists offers assorted institutions easily acquired tools with multiple functions. It is also a method with a constantly developing potential – progress in photography can render RTI even more effective.

Przypisy

[1] S.M. Duffy, P. Bryan, G. Earl, G. Beale, H. Pagi, E. Kotoula, *Multi-light Imaging for Heritage Applications*, English Heritage 2013, https://content.historicengland.org.uk/ images-books/publications/multi-light-imaging-heritage-applications/Multi-light_Imaging_FINAL_lo w-res.pdf [dostęp: 24.06.2014]; T. Malzbender, D. Gelb, H. Wolters, B. Zuckerman, *Enhancement of Shape Perception by Surface Reflectance Transformation*, Hewlett-Packard Technical Report HPL-2000-38R1, 2000, http://www.hpl.hp.com/techreports/2000/HPL-2000-38R1.pdf [dostęp: 10.05.2016]; T. Malzbender, D. Gelb, H. Wolters, *Polynomial Texture Maps*, w: red. *SIGGRAPH '01 Proceedings of the 28th annual conference on Computer graphics and interactive techniques*, New York 2001, s. 519-528.

[2] Cultural Heritage Imaging, *Reflectance Transformation Imaging: Guide to Highlight Image Capture. Document version 2.0*, San Francisco 2013, http://culturalheritageimaging.org/What_We_Offer/Downloads/RTI_Hlt_Capture_Guide_v2_0.pdf [dostęp: 05.05.2016].

[3] *Ibidem*; West Semitic Research Project, *MANUAL for Reflectance Transformation Imaging (RTI) Photography For Large Objects*, 2015, https://www.usc.edu/dept/LAS/wsrp/projects/RTI%20Manual%20LARGE%20OBJECT%205_29_2015.pdf [dostęp: 10.05.2016]; West Semitic Research Project, *MANUAL for Reflectance Transformation Imaging (RTI) Photography For Small Objects*, 2015, https://www.usc.edu/dept/LAS/wsrp/projects/RTI%20Manual%20SMALL%20OBJECT%205_29_2015.pdf [dostęp: 10.05.2016].

[4] E. Kotoula, *Application of RTI in Museum Conservation*, w:, *Archaeology in the Digital Era, Volume II. e-Papers from the 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA), Southampton, 26-29 March 2012*, G. Earl, T. Sly, A. Chrysanthi, P. Murietta-Flores, C. Papadopoulos, I. Romanowska, D. Wheatley (red.), Amsterdam 2013, s. 232-240, http://dare.uva.nl/cgi/arno/show.cgi?fid=545855 [dostęp: 10.05.2016]; M. Mudge, T. Malzbender, C. Schroer, M. Lum, *New Reflection Transformation Imaging Methods for Rock Art and Multiple-Viewpoint Display*, w: *VAST 2006: The 7th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, Nicosia, Cyprus, 2006. Proceedings*, D. Arnold F. Niccolucci, M. Ioannides, K. Mania (red.), Aire-la-Ville 2006, s. 195-202; K.E. Piquette, *Reflectance transformation imaging (RTI) and ancient Egyptian material culture*", *"Damqatum The CEHAO newsletter" 2011, s. 16-20,* http://bibliotecadigital.uca.edu.ar/repositorio/revistas/ancient-egyptian-material-culture-piquette.pdf [dostęp: 01.03.2018]; D. Selmo, F. Sturt, J. Miles, P. Basford, T. Malzbender, K. Martinez, C. Thompson, G. Earl, G. Bevanf, *Underwater reflectance transformation imaging: a technology for in situ underwater cultural heritage object-level recording*, "Journal of Electronic Imaging" 1/2017, No. 26, s. 1-18.

[5] Cultural Heritage Imaging, *Reflectance Transformation Imaging: Guide to Highlight Image Capture. Document version 2.0*...

[6] Cultural Heritage Imaging, *Reflectance Transformation Imaging: Guide to Highlight Image Processing. Document version 1.4 for RTIBuilder v. 2.0.2beta*, San Francisco 2011, http://culturalheritageimaging.org/What_We_Offer/Downloads/rtibuilder/RTI_hlt_Processing_Guide_v14_beta.pdf [dostęp: 10.06.2017].

[7] Cultural Heritage Imaging, *Reflectance Transformation Imaging: Guide to RTIViewer. v1.2*, San Francisco 2013, http://culturalheritageimaging.org/What_We_Offer/Downloads/rtiviewer/RTIViewer_Guide_v1_1.pdf [dostęp: 05.05.2016].

[8] http://graphics.cs.yale.edu/site/cher-ob-open-source-platform-shared-analysis-cultural-heritage-research [dostęp: 15.03.2018].

[9] http://inscriptifact.com/instructions/Viewer_Instructions.pdf [dostęp: 15.03.2018].

[10] L.W. MacDonald, *Visualising an Egyptian Artefact in 3D: Comparing RTI with Laser Scanning*, w: S. Dunn, J.P. Bowen & K.C. Ng (red.), *EVA London 2011: Electronic Visualisation & the Arts. Proceedings of a conference held in London 6-8 July*, London 2011, s. 155-162.

[11] Zob. G.P. Earl, K. Martinez & T. Malzbender, *Archaeological Applications of Polynomial Texture Mapping: Analysis, Conservation and Representation*, "Journal of Archaeological Science" 2010, No. 37, s. 2040-50; J. Padfield, D. Saunders & T. Malzbender, *Polynomial Texture Mapping: A new Tool for Examining the Surface of Paintings*, w: *The 14th Triennial Meeting, The Hague Preprints. Vol. I. ICOM Committee for Conservation*, I. Verger (red.), London 2005, s. 504-510; G. Willems, F. Verbiest, W. Moreau, H. Hameeuw, K. Van Lerberghe, L. Van Gool, *Easy and cost-effective cuneiform digitizing*, w: *Proceedings of 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2005)*, M. Mudge, N. Ryan & R. Scopigno (red.), Aire-la-Ville 2005, s. 73-80; M. Díaz-Guardamino & D. Wheatley, *Rock art and digital technologies: the application of Reflectance Transformation Imaging (RTI) and 3D laser scanning to the study of Late Bronze Age Iberian stelae*, "*MENGA. Journal of Andalusian Prehistory" 2013*, No. 4, s. 187-203; E. Kotoula & M. Kyranoudi, *Study of Ancient Greek and Roman coins using Reflectance Transformation Imaging*, "e-conservation magazine" 2013, No. 25, s. 74-88; M. Mudge, C. Schroer, T. Noble, N. Matthews, S. Rusinkiewicz, C. Toler-Franklin, *Robust and scientifically reliable rock art documentation from digital photographs*, w: *A Companion to Rock Art*, J. McDonald & P. Veth, (red.), Malden & Oxford 2012, s. 644-659; M. Pitts, J. Miles, H. Pagi, G. Earl, *Hoa Hakananai'a: A new study of an Easter Island statue in the British Museum*, "The Antiquaries Journal" 2014, no 94, s. 291-321; P. Witkowski, J. Chyla, W. Ejsmond, *Combination of RTI and Decorrelation – an Approach to the Examination of Badly Preserved Rock Inscriptions and Rock Art at Gebelein (Egypt)*, w: *Keep The Revolution Going: Proceedings of the 43rd Annual Conference on Computer Applications and Quantitative Methods in Archaeology*, S. Campana, R. Scopigno & G. Carpentiero (red.), Oxford 2016, s. 939-944.

[12] M. Díaz-Guardamino, L. García Sanjuán, D. Wheatley, V. Rodríguez Zamora, *RTI and the study of engraved rock art: A re-examination of the Iberian south--western stelae of Setefilla and Almadén de la Plata 2 (Seville, Spain)*, "Digital Applications in Archaeology and Cultural Heritage" 2015, No. 2, s. 41-54.

[13] M. Manfredi, G. Williamson, D. Kronkright, E. Doehne, M. Jacobs, E. Marengo, G. Bearman, *Measuring Changes in Cultural Heritage Objects with Reflectance*

Transformation Imaging, w: *Proceedings of the Digital Heritage 2013, 28 October – 1 November 2013, Marseille, France, Vol. 1, 2013*, A.C. Addison, G. Guidi, L. de Luca & S. Pescarin (red.), Marseille 2013, s. 189-192; M. Manfredi, G. Bearman, G. Williamson, D. Kronkright, E. Doehne, M. Jacobs, E. Marengo, *A New Quantitative Method for the Non-Invasive Documentation of Morphological Damage in Paintings Using RTI Surface Normals*, "Sensors" 2014, No. 14, s. 12271-12284.

[14] M. Chłodnicki, D. Bagińska & P.L. Polkowski, *Rock art*, *Archaeology of the Sudan. Catalogue of the Exhibition in the Poznań Archaeological Museum*, Poznań 2015, s. 291-302.

[15] https://imagej.net/Welcome [dostęp: 15.03.2018].

[16] http://www.dstretch.com/ [dostęp: 15.03.2018].

dr Paweł Lech Polkowski
Archaeologist specialising in research on the rock art of Egypt and Sudan; works at the Archaeological Museum in Poznań – custodian of Rock Art Unit and curator of the permanent exhibition: "Rock Art of North Africa"; head of research on petroglyphs in Dakhleh Oasis (Egypt); e-mail: pawel.polkowski@muzarp.poznan.pl

Piotr Witkowski
Specialist on modern forms of documentation, studies at the Institute of Archaeology at the University of Warsaw; one of the pioneers of the application of RTI in Poland – currently conducts research on the development of this method and analyses based on the RTI image by co-operating with the Archaeological Museum in Poznań and taking part in an archaeological expedition in Gebelein (Upper Egypt); won archaeological experience in the course of field work both at home and abroad (Turkmenistan, Iran, Lebanon, Egypt); e-mail: pwitk@wp.pl

Word count: 4 058; **Tables:** –; **Figures:** 9; **References:** 16
Received: 03.2018; **Reviewed:** 03.2018; **Accepted:** 04.2018; **Published:** 05.2018
DOI: 10.5604/01.3001.0012.0619

Competing interests: Authors have declared that no competing interest exits.
Cite this article as: Polkowski P.L., Witkowski P.; REFLECTANCE TRANSFORMATION IMAGING. ABOUT A PHOTOGRAPHIC METHOD FOR THE DOCUMENTATION AND ANALYSIS OF MONUMENTS. Muz., 2018(59): 54–62
Table of contents 2018: https://muzealnictworocznik.com/issue/10809