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Standardized Reflection Transformation Imaging (RTI) for Documentation and Research

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Abstract

Reflection Transformation Imaging (RTI) is a powerful tool to capture the surface of an object for later examination [1]. We brought RTI to the next level regarding reproducibility, simplicity and image quality [2]. Besides the possibility to capture the surface topography, we can measure and reproduce materials composed of complex reflectance behaviours, with high colour and gloss fidelity. Full-featured cross-platform software for the creation and viewing of such enhanced RTIs has been developed and commercialized. The application allows simple interaction and comparison of RTI datasets.

However, the crucial feature of RTIs is their interactivity and the possibility to individualize viewing configurations for specific surface examinations. In the context of image interoperability, it is essential to be able to describe such viewing configurations to ensure reproducibility, e.g. in case of collaborative work.

The trend of linked open data shows that RTIs as well must follow open access rules. The success of standardized access to image data is demonstrated well by the international image interoperability framework (IIIF).

In this paper, we address two issues: The importance of standardized web-access to RTI data as well as an approach to store and disseminate specific RTI viewing configurations.

Motivation

Photographs in general and RTIs, in particular, are essential for the documentation of cultural heritage artefacts as well as for the digital dissemination of objects with limited access [3][4]. Such digital reproductions allow transport of visual attributes of objects over the internet. In the most typical case photographs are shared as image data, in formats like JPEG or PNG or, if better data quality is needed, high-resolution TIFF or JPEG2000 files are exchanged. A digital photograph represents an original statically. Therefore rendering is straight forward, and there is only little room for interpretation in a technical sense. An image transferred by the internet and rendered at two different clients will essentially look the same. Misinterpreted colour profiles are potential sources for differences. The room for interpretation at the level of an observer is limited as well. A photograph shows an artefact from one static perspective, and with one static illumination. In an optimal situation, the photographic image is captured in such a way, that the significant information is transferred correctly.

If we leave the domain of conventional photography and move to higher dimensionality, the situation changes significantly. For example in the case of 3D scans, it is obvious, that it is not sufficient to define just the surface by a wire mesh and a texture that coats the surface. For full scene definition, a viewpoint and a clear definition of the light setting is necessary. Only if all those attributes are defined, different viewers can view the identical rendering. Besides data of the volume model, a set of technical metadata is necessary for complete scene definition.

The same is true with RTIs; even they different from standard 3D scan data. An RTI as we know it today is a photographically gained image that allows interactive illumination with one or more light sources. Normal vectors represent surface topography of the object. The technology we use for rendering an RTI in a browser is WebGL in a standard web canvas element, as it is defined in HTML5, the same as for 3D mesh data representation.

In such a canvas element an RTI visualization is composed as a 3D scene: The RTI has a position in space, it is looked at from a specific position, and there are one or more light sources that illuminate the virtual , defined interactively by the observer. Therefore the possibilities for scene interaction are countless. The increase in individualization while rendering in comparison to conventional photography is certainly of advantage but demanding. To ensure reproducible renderings, settings (meta-data) for scene definition are necessary.

We see a significant need for such technical metadata to ensure interoperability of RTI and 3D data for research, teaching, and publication in the web.

Problem

For research and teaching, it is essential to be able to exchange and discuss image content. An Application Programming Interface (API) is the typical way to access images stored in a repository via the internet. If the protocol is known an application can load and render image data on request. Like this digital image data can be discussed by various researchers, localized in different universities or labs. In the case of image data, there is a very promising initiative and fast-growing community that takes care of such a standardized API to load image resources: The International Image Interoperability Framework (IIIF)[5]. IIIF is a standard to access image resources over the internet using the HTTP protocol. The principle approach of IIIF is the access of image data, that is configured on demand. In other words, an image is stored only as one high-quality version on an IIIF compliant server[6]. The master image has the required maximum quality in regards to resolution, bit depth or other image attributes. If a web-client requests such a specific image, the copy for dissemination is created based on the parameters transmitted while accessing the image server. For example, a change of resolution, image rotation or image crop is applied on-the-fly based on parameters in the URL transmitted from the client to the image server. The server then derives the required image from the master file and sends the image data using the HTTP protocol back to the requesting client. The concept is advantageous because a server needs only to store one version of the image, which is identical to the archival master. The generation of derivatives happens on request. Such a standardized way of image requests allows new and innovative applications.

A good example is the e-codices project[7], a virtual library of medieval handwritten books. Due to the fact of a standardized API, the various source images can be combined into a virtual collection, even if the original artifacts are spread all over the world. It is, e.g. possible to combine multiple image resources in the same viewer application to compare them.

Like this, it is possible to compose a virtual book, based on digital images of fragments of pages of ancient books coming from different source repositories, with only one viewer application and one API implementation. Unfortunately, the concept of standardized image access, as defined by IIIF, is limited to raster graphics image data so far.

In the case of RTIs, such standardization of data or access does not exist up to now, although RTIs are even more capable of exchanging relevant information about the artefact's surface between scholars. Standardized access to RTIs would mean more straightforward data exchange and image render possibilities, e.g., in web applications. In principle, the communication interface (API) to RTI image resources is more difficult than an API to conventional raster image data. Besides image size, rotation and cropping, an RTI has much more attributes for the definition of types and positions of light sources, viewpoints, and virtual surface enhancement. All those attributes must be supported by an appropriate API to be able to load RTI image data reproducible.

Approach

A standardized RTI API is the definition of accessing an RTI data object and the technical meta information about a full scene. A scene is composed of the object data of proper quality [8], a viewpoint location, view direction, n light sources (color-temperature, geometry, ...) and their position and orientation in the scene. Such a standardized interface allows access to RTIs stored in different repositories. It simplifies the implementation of RTI viewing tools as well as data exchange between storage archives. If technical metadata is standardized, settings of the web-application for rendering and visualization of RTIs can be stored and exchanged. If, for example, a researcher requests image data from a standardized RTI compliant repository, he can adjust his scene as wanted in any compliant viewing application. In a second step, all necessary technical meta-information can be stored as a meta-data set called Individual Scene Rendering Definition (ISRD). Such an ISRD defines an exact rendering situation, that can be exchanged with other scholars to discuss specific viewing situations of a scene, loaded with the API, in detail. If multiple RTIs are compared, the data resources can either be loaded with the API and default settings or various ISRDs can be applied to specify the various renderings of the requested RTI scenes.

There is a standard scenario that describes best the process: On API request, the server delivers the full data set in a standardized way as well as a corresponding ISRD. Based on that information the RTI is rendered on the client machine based on the ISRD settings.

The technical implementation requires various layers of functional parts:

- The definition of a full-featured RTI format is needed, that has the required capability to be used as an RTI image data container.
- The format must consist of technical metadata for full scene definition. It includes light source positions, light source types, light source shapes, viewpoint, viewpoint settings like magnification and information about the background. We call the full set of metadata about a scene the Individual Scene Rendering Definition (ISRD).
- An IIIF like RTI compliant server, that is capable of calculating and delivering RTI image data on request based on a standardized URL syntax[5].
- A standardized viewer is required, that is capable of rendering one or more RTIs based on the ISRD.

The definition of ISRDs is very promising for the practical application of RTIs. Most researchers use RTIs to examine a surface in detail in a virtual space. E.g. in archaeology time available with the original is very limited in most cases. If an artefact is transferred properly into the digital domain as an RTI, the examination of surface details can be done afterwards and in detail. If a relevant viewing situation is found, the ISRD can be stored and shared with another researcher or a community. The scene can then be the starting point of new examinations, leading step by step to results of new quality, based on the knowledge of various experts. Alternatively, such a set of scene specific metadata can be used for 2d and 3D storytelling in museum communication [9][10].

Results

A standardized RTI API is the definition of the protocol for accessing RTI data objects and the technical meta-information necessary to describe a full scene. A scene is composed of the object data, a viewpoint location, view direction, n light sources (colour-temperature, geometry, ...) and their position and orientation in the scene.

A potential schema of a RTI image API could look like this:
{scheme}://{server}{/prefix}/{identifier}/{viewpoint}/{rotation}/{diffuse}/{gloss}/{color}/{lights}

- scheme: “http” or “https”;
- server: DNS name;
- prefix: arbitrary name;
- identifier: unique identifier of an image;
- viewpoint: a set of tree coordinates defining the viewpoint. The object is placed at the centre of the system of coordinates (i.e. x=0, y=0, z=0);
- direction: view direction (3D vector)
- diffuse: intensity of the diffuse material component (value between 0 and 1), see reference[2] ;
- gloss: intensity of the gloss material component (value between 0 and 1), the sharpness of gloss (integer value between 50 and 125), see reference[2];
- colour: “default”, “specular enhance” extensively used feature of RTI visualization, where the colour of the surface is removed and the gloss is artificially enhanced, resulting in a metallic appearance, that allows the scholar to recognise features on the surface;
- lights: JSON object composed of N entries, each representing an independent light source and qualified by the proprieties like: “type” (e.g. directional, point source, diffuse, etc.), “position” , “direction” (coordinates of the normalized vector describing the direction of the light source), “intensity” (intensity of the light source, value between 0 and 1), “color” (RGB value).

An example of a full chain of technologies to generate, store, transmit and render RTIs in web-environments will be shown. Besides that, a file format will be demonstrated, that allows storing all necessary information about the object surface (the RTI model data) as well as the scene. Based on that file format RTIs can be stored in a sustainable way, so that reusability and interoperability are guaranteed.

Conclusions

Standardizing RTI is a step towards an easier and more interoperable way to share that kind of image data. It allows for new possibilities in the application of RTIs and it is an advantageous step for the documentation and the exchange of artwork based on web technologies. Transferring RTI data from various repositories in different locations is important for many research projects. An API is not only the state-of-the-art interface technology, but it is also the key for content-based information exchange. If an API is provided data can be merged at any site without limitations. An API is also the key element to be able to apply software tools (e.g. a web application) to RTI image data that is stored at any repository, providing a compatible API for data access.

There is a strong tendency, that tools for visualization, modification, and analysis of data objects like RTIs, are composed in larger digital infrastructures, called Virtual Research Environments. A VRE that has been developed at the DHLab is *Knora* [11]. In a proof of concept, an RTI API will be implemented at the DHLab of the University of Basel (CH) and at a site of the University of Strasbourg (F). The interfaces will allow the communication and exchange of RTI scene data between the two data centre. In addition, a collaborative RTI viewer will be implemented to test user acceptance in research and teaching. With such a VRE as a back-end, RTI images can be annotated, enriched with comments and interlinked with other objects that are stored in the repositories, like sound, text, photographs or any other digital facsimile.

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Author Biography

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Andrea Bianco is a co-founder of Truvis AG and software developer in the company. Bianco has a master and a Ph.D. in Physics. He is an experienced imaging expert and he has a deep insight into web-technology. Truvis is a start-up from the University of Basel. The company has commercialized RTI software and hardware technology

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