Reflectance Transformation Imaging Proposal

Johannes Goslar

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1 Background

Cultural Heritage Imaging describes Reflectance Transformation Imaging as following[2]:

> RTI is a computational photographic method that captures a subject's surface shape and color and enables the interactive re-lighting of the subject from any direction. RTI also permits the mathematical enhancement of the subject's surface shape and color attributes. The enhancement functions of RTI reveal surface information that is not disclosed under direct empirical examination of the physical object.

To generate the initial data the to-be-analysed object is placed under a specially crafted dome, which inner hull is sprayed matte black and has single controllable light sources spread out. The top of the dome has a hole in which a camera objective fits. Each light source is lighted in order and a picture is taken with only that light source shining. These images are then transferred to a computer, where a first program analyses this raw data and repackages it for later use in RTI viewers. Within these RTI viewers, the user can manipulate the lightning to reveal previously hidden information. The University of Oxford is a hub for RTI research, but the main interest was so far from the Faculty of Classics and the School of Archaeology, which use RTI processes to analyse archaeological artefacts.[1] Of particular note is the current effort to further uncover the meaning of the so-called 'Bloomberg tablets', which are the remains of 405 Roman wax tablets, dating from 50 AD to 80 AD. Only the wood remains of these tablets, but scratches in the wood relate to the once written text A further complication is the occurred reuse of these tablets, multiple texts can overlap each other.[3] RTI can help reveal the information by replacing and automating two human eyes and a light torch by the means discussed above. The thesis will aim to integrate the Department of Computer Science with the ongoing research and finally provide the other stakeholders with better software to achieve their goals.

2 Open Questions

The open questions range from questions specific to the Oxford RTI setup to general applicable questions, the following areas can likely be forwarded as part of the thesis:

- How can the Oxford RTI setup be further automated? Currently objects are placed by hand, the images are transferred by hand, manual preprocessing steps are required, disk space is constrained, etc.
- Can RTI be an interesting part of the 'Physically Based Rendering' course? The course features some slides already, but a practical could further help the understanding. A practical element would work best with an extensible RTI core, for which new modules could be written each term the course is held.
- Can modern software engineering and modern user experience design help the researchers uncover information faster? Most RTI software has limited support for different operating systems, supported RTI domes, image input formats and is generally specific to the circumstances the author was in. None is featuring an extensible, modular design, which others could write plugins for.
- Can integrated collaboration features support the inquires? All current RTI software only supports a single-user process. No settings can be shared live, no annotations are synchronized automatically, no connectivity is provided. An online/cloud based background service integrated into the RTI viewer could potentially implement this feature set.

These are interesting, but the time frame will likely prohibit the answering:

- Do precalculated lightning angles improve the resulting images? Currently, a glossy billiard ball is placed alongside the analysed object and the lightning angle is calculated from the specular reflection on this ball. Given automated object placement and centring, the actual angles could be measured inside the (custom-build, one-of) dome and then used instead.
- Can machine learning be used to automatically extract hidden textual information from RTI images? Building on the proposed annotation feature to create labelled data could machine learning principles be used on regions of the raw RTI image to automatically run through different lightning configurations and reveal the previously hidden letters?

3 Proposed Method

The common denominator of all questions above is the need to have an extendable RTI base, which should provide hooks and plugin options for more specific

use cases. As no RTI base is available, this thesis will develop this basis and an initial set of plugins. Preliminary discussions ended with the likely technology stack of:

- Use of web technologies (ECMAScript, HTML, CSS), so the viewing component can be used from any web browser and the analysis component can be run locally inside an 'electron' shell to have fast access to the raw data (up to 6GB for one object)
- Use of TypeScript as the main implementation language, as it allows a typeable API for plugins, which plain ECMAScript would not allow
- free software under GPLv3, available on open source platforms like Github to allow community collaboration

Based on this core the next step will be to achieve parity with the current RTI analyser and viewer, for which the Oxford Centre for the Study of Ancient Documents will provide raw datasets and the currently calculated RTI images. After parity is reached the focus will switch to the implementation of the plugins proposed above. The given timeframe will unlikely be sufficient for a comprehensive addition of the machine learning component, as enough labelled data is unlikely to suddenly available, and likely will have to be done in further research. The final step will be a user study with the Oxford RTI hub to evaluate if the implemented plugins helped to uncover more information faster, the fixing of revealed bugs in the evaluation and the best possible accommodation of occurring wishes from the end users.

4 Draft Timetable

The thesis has to be completed by end of August, which gives a timeframe of 18 weeks, including 1.5 weeks for sickness and 1.5 for other hiccups, leaves 15 weeks, which will be split up accordingly:

1 - 3 Collection of requirements of all stakeholders, evaluation of reusable code from the current viewers, completion of the introduction part of the thesis and architecture of the base

4 - 6 Implementation of the new RTI program base, documentation inside the thesis, completion of the rollout and distribution pipelines.

7 First rollout to Oxford-based users and first user feedback cycle to identify potential problems early.

8 - 11 Implementation of the proposed plugins and writing of their documentation. Completion of the technical part of the thesis.

12 - 13 Feature freeze, second rollout and public release, followed by the user study and evaluation.

14 - 15 Conclusion of user study, future outlook, final additions and proofreading of the thesis.

References

[1] Graeme Earl et al. "Reflectance transformation imaging systems for ancient documentary artefacts". In: (2011).

[2] *Reflectance Transformation Imaging (RTI)l*. URL: `http://culturalheritageimaging.org/Technologies/RTI/` (visited on 04/22/2018).

[3] *UK's oldest hand-written document 'at Roman London dig'*. URL: `https://www.bbc.co.uk/news/uk-england-london-36415563` (visited on 04/22/2018).