



Bachelor's Thesis

Designing and Implementing a Rephotography Application for iOS

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INTRODUCTION

This chapter will introduce the notion of rephotography, elaborate on the process of how to make such a photograph and evaluate existing approaches to simplify it. These include two applications for mobile operating systems which will be briefly discussed. Furthermore, a summary of more sophisticated work by MIT researchers will be given, leading to the problem statement and the goal of this work.

1.1 OVERVIEW

Rephotography or repeat photography denotes the retrieval of the precise viewpoint used for taking a — possibly historic — photograph and capturing another image from the same spot, ideally with the same camera parameters. This allows for documentation and visualisation of changes which the scene has undergone between the two or more captures. For instance when documenting urban development, one can present progress of construction, restoration efforts or changes in the surroundings in a visually striking manner, e.g. by blending the photographs together. Figures [Figure 1](#) and [Figure 2](#) show examples.

When done manually, the photographer must attempt to find the original viewpoint usually by visual inspection of the original image and trying to match the current camera parameters — camera position, camera rotation, focal length, possibly principal point — to the original. The procedure is often carried out by placing the camera on a tripod and comparing a printout of the original image with what can be seen through the viewfinder or the camera screen. The number of parameters to match as well as the difficulty to estimate them purely from comparing two-dimensional images makes the process error-prone and tedious. Visual acuity and experience of the photographer thus place limits on the accuracy with which the camera pose of the reference image can be reconstructed. Some corrections can be done by post-processing the images and warping the rephotograph with a homography to better match the original.

At the time of writing, few computerized aids are available to the photographer (see below). The advancement of mobile phones and tablet computers with integrated cameras and larger screens presents the opportunity to develop applications which can assist in this endeavour, moving away from the traditional trial-and-error approach. On current digital cameras¹ this is impossible due to their closed infrastructure not permitting running user programs.

¹ At the time of writing, no commercial manufacturer produces a camera with user-modifiable firm- or software. A project at Stanford ([Adams et al., 2010](#)) was discontinued [Levoy \(2009\)](#)



Figure 1: Residenzschloss Dresden, destroyed during World War II, © Sergey Larenkov, printed with permission



Figure 2: Frauenkirche Dresden, destroyed during World War II, © Sergey Larenkov, printed with permission

1.2 PREVIOUS APPROACHES

1.2.1 *Mobile Applications*

Two applications have been developed to assist a photographer in taking rephotographs. For smartphone operating systems, *rePhoto*² and *Timera*³ exist, both available for Android and iOS devices. These applications support the user by placing a transparent version of the original image over the current camera image, allowing for easier alignment. The captured rephotograph is then presented together with the original image in a blend (c.f. ??) which can be customized in *Timera*.

What is characteristical about both of these applications is that the user must still determine on their own how to actually move the camera. An overlay simplifies the procedure, eliminating some of the inaccuracy introduced into the manual approach by the necessity to move the eyes from printout to camera, but it is still the user's responsibility to determine the necessary motion between the current camera position and the goal position (that of the original image).

1.2.2 *Computational Re-Photography*

A more sophisticated automated approach was presented in (Bae et al., 2010) by MIT researchers in 2010. In this setup, the relevant parameters of a historic image's camera are reconstructed, including the focal length, principal point and the six degrees of freedom in camera pose and after reconstructing the scenery in 3D by use of two images captured by the user, they are then directed by the software to the desired viewpoint.

Bae et. al identify five primary obstacles in viewpoint reconstruction of a historic photograph

1. The necessary camera motion has six degrees of freedom — three for translation and three for rotation — which are challenging for the user to adjust simultaneously, as changing one parameter will often necessitate adjustments for the others to improve the matching. Furthermore, the number of degrees of freedom makes it difficult to communicate to the user, how they must move the camera.
2. 3D reconstruction is possible only up to an unknown scale (see ??), meaning it is impossible to determine e.g. if an object viewed by the camera is small and close or large and further away. This poses the problem of how to determine if the user is close to the desired viewpoint and whether or not they have come closer or moved further away over iterations.
3. Relative pose estimation from corresponding points fails when the motion between the two cameras approaches zero, which is

² <http://projectrephoto.com/>

³ <http://www.timera.com/Explore>

the ultimate goal one wishes to achieve. When naïvely comparing the current camera image to the reference photograph, the estimate for relative rotation and translation becomes increasingly unreliable as the camera approaches the original viewpoint.

4. Automated computation of relative camera pose will rely on feature detection to find correspondences. However, historical images will often be vastly different from the current scene. Not only may the scene itself have changed considerably, but also the historical image — having been taken by a historical camera — may differ in contrast, sharpness and colours. Feature detectors may not be able to reliably find correspondences when comparing an old with a new photograph.
5. The calibration data — most importantly, focal length and principal point — of the historical camera are often unknown. The calibration data is needed for relative pose computation.

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