# Freezing Fire – Automated Light-Passes for Stop-Motion VFX

Paulo Scatena
paulo.scatena@filmakademie.de
Filmakademie Baden-Württemberg
Ludwigsburg, BW, Germany

**Figure 1: Rendered frames of combined physical set and CG element.**

## ABSTRACT

This work proposes and evaluates a method of image-based rendering for integrating light-emitting CG assets with digital photography. The framework consists of a capture stage, in which footage of the scene under varied lighting is acquired, and a reconstruction stage, which outputs the calculated light contribution of the CG element upon the scene. This form of relighting is novel as it embraces scenarios where the light source is intended to be in the frame. The freedom to introduce emissive objects in post opens creative room for light animation and was assessed here as employed in the production of a stop-motion short-film.

## CCS CONCEPTS

• **Computing methodologies → Image-based rendering**; • **Computer systems organization → Robotic control**.

## KEYWORDS

relighting, robotics, compositing, stopmotion animation, image-based rendering

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## 1 INTRODUCTION

Realism, when combining CG assets and film, lies in how convincingly light interacts with all elements. Several techniques cover how to render content for it to look as if pertaining to a shot scene. However, editing the footage for it to "react" to said assets is not as straightforward, particularly if light emission is introduced. Post-capture changes require heavy image manipulation. Practical solutions offer limited help: stand-in lights call for additional clean-up, and available tools[Labs 2017] and approaches[Huang et al. 2018] for creative light-painting are bounded to the time of the shoot.

A proposed alternative is to capture a number of images from the scene lit only by a point light placed in distributed positions in space. An image-based rendering can be generated in post, corresponding to how the scene would be illuminated if the emissive object was physically present. Compared to existing techniques[Wenger et al. 2005], a key difference arises: the objective here is to recreate not the external light response *upon* an isolated object, but instead, the light response *from* an asset upon its environment.

This technique offers a solid middle ground for the compositing of CG elements over footage, without the need for image manipulation or 3D replicas. Due to its post-capture nature, static scenes can be "brought to life" with light animation. Different approaches to capture and reconstruction were assessed, and its use in production was evaluated as part of the VFX pipeline of a short film.

## 2 METHODS

The crudest form of image-based relighting comes for direct interpolation of images captured under different lighting. For initial proof of concept, a single light was placed evenly in space, and the associated photographs were blended together with corresponding weights. The source light itself was masked out, so that the combined output represents only its ambient contribution.

For denser data acquisition, video recording was used. A mechanical rig was built to move a LED along a helix path, with its position tracked by an encoder or inferred via computer vision. Handheld movement was also tested, coupled with spatial tracking. It allows the light to be placed around existing scene objects, and is an accessible approach for light reconstruction over a single capture (e.g. product photography). However, consistency is compromised.


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Thus, a small robotic arm was employed, together with a dedicated C++ application written for time parameterized operation. A digital replica was rigged in Autodesk Maya, for its movement to be designed and timed in a flexible, artist-friendly manner. The resulting path was passed as instructions to the physical robot. This approach allowed for unvarying recordings, with results dependable enough to enable its use in stop-motion animation.

## 3 USE IN PRODUCTION

A stop-motion short film was coupled with this research. It required convincing integration of a fire-like element, visible in most of the film. From a total of 32 shots, 23 would need VFX solutions for the asset integration, adding up to 90 seconds of screen time.

For relighting to be employed, guidelines were the consistency of results from different captures, data organization and reduced interference in the animator's work. Automation was a key part of the solution. Camera, lights, computers and robotic arm were connected via serial communication. A Bluetooth-paired tablet device assisted data organization through metadata assignment. Each shot required specific light paths and calibrations between camera and robot position. For every animated frame, quick recordings were made under varied environment lights, followed by a longer recording of the moving LED. Capture time ranged from 10 to 40 seconds per stop-motion frame, depending on desired density. The total acquired footage consisted of 5680 clips (590GB of data). Of that, 865 clips (15%) correspond to the moving LED, taking up most of the storage space (542GB, or 92%).

**Figure 2: Different renders from the same captured scene.**

In post-production, the CG asset was designed and rendered within SideFX Houdini, where the recorded path of the LED was introduced for calculating the relighting weights. In Nuke, the footage was sorted, masked and reassembled. Clean plates were also rendered with light animation, as a support for rig removal

Compositing was, compared to standard VFX practice, less occupied with heavy image manipulation, and freed to focus on balancing the light passes and adding final creative touches.

## 4 DISCUSSION

Image-based relighting techniques for in-frame VFX were tried and evaluated in this work. Results were consistent, providing light passes that assisted convincing integration of digital effects over practical sets. The method was valuable for a short-film production, offering the freedom to fix design choices in post-production, without sacrificing the tactile feel so typical of stop-motion.

Since a single acquired data set allows for multiple output possibilities, the use of this technique is appealing for commercial photography and product-based advertisement, with light animation adding dynamism to an otherwise static frame. With the increasing presence of collaborative robots in creative studios, similar approaches could become part of the production pipeline.

Results are dependent on the quality and density of the recorded data, and benefit from favorable scene elements (i.e., of high surface roughness). Image interpolation may lead to ghosting or specular artifacts. Rendering is data-intensive, so interactivity is limited. More efficient storage and processing of data would the most immediate improvements. This method can also borrow from current research on extending light-fields[Bemana et al. 2020] and relighting data sets[Sun et al. 2020], solving the limitations from mere image interpolation. Such advances, coupled with robust automation, would open room for faster capture times and/or extended capture volume, providing increased creative freedom in post-production.

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