December 2021

Enabling Enhanced Super-Resolution Photography Using Haptics Motor Vibration During Burst-Mode Capture on Smartphones

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Abstract:

This publication describes implementing enhanced super-resolution photography using haptics motor vibration during burst-mode capture on computing devices (e.g., smartphones). A novel framework generates sub-pixel shifts in burst-mode capture by activating a smartphone haptics motor to move a camera in a particular haptic pattern while capturing multiple images. Information regarding the haptic pattern is used to compensate for the sub-pixel shifts during image processing to generate an image with increased resolution.

Keywords:

super-resolution, high-resolution, burst mode, photography, imaging, haptics, smartphone, camera, hand motion, hand movement, vibration

Background:

The camera of a smartphone may be used for taking high-resolution photos. Long-range photography and near-field microscopic detail recovery are examples of techniques for capturing high-resolution images with a smartphone. Super-resolution techniques can be applied to one or more low-resolution or high-resolution photos to produce an image of even higher resolution.

Super-resolution photography on a smartphone can be accomplished through a couple different techniques: single-shot super-resolution and burst-mode capture with super-resolution. Single-shot super-resolution relies on software to anticipate unknown high-resolution pixels in a single photograph by interpolation from known pixels. The software extensively relies on prior assumptions of natural scenes containing spatially coherent objects to anticipate pixel values. For example, if a 2 x 2 grid of pixels contain a blueish color, then increasing the resolution to a 4 x 4 grid of pixels using interpolation will likely result in new pixels similarly exhibiting the blueish color. However, interpolation techniques can only provide an estimation of pixels. The resulting image may have artifacts (e.g., edge blurring, oversimplification), which are problematic for achieving a desired level of resolution.

The other technique is burst-mode capture with super-resolution, which is designed to improve on single-shot super-resolution. For example, a camera on a smartphone takes a burst of photos at an extremely fast rate. The smartphone then computes sub-pixel shifts resulting from motion of a user's hand while holding the smartphone and taking the burst of photos. Using the computed sub-pixel shifts, an algorithm is applied to compensate for the shifts by anticipating pixel values, in an attempt to create an image with increased resolution. However, the algorithm must make assumptions regarding the magnitude of sub-pixel shifts and inaccurate assumptions may result in poor image quality.

Description:

The problems inherent in common super-resolution photography techniques of providing a mere estimation of pixels and making algorithmic assumptions regarding the magnitude of sub-pixel shifts are solved by utilizing a haptic motor to create movement of a camera during the capture of multiple images and accounting for the associated haptic movement during image processing, as disclosed in this publication. Burst-mode capture photography with enhanced super-resolution photography techniques can combine multiple images of a scene to produce a single image of increased resolution. During burst-mode capture photography, the camera moves while capturing multiple low-resolution images at a high rate. The multiple low-resolution images undergo image registration to identify integer pixel shifts and subpixel shifts. After image registration, the multiple low-resolution images undergo projection with one or more super-resolution methods, resulting in a single high-resolution image.

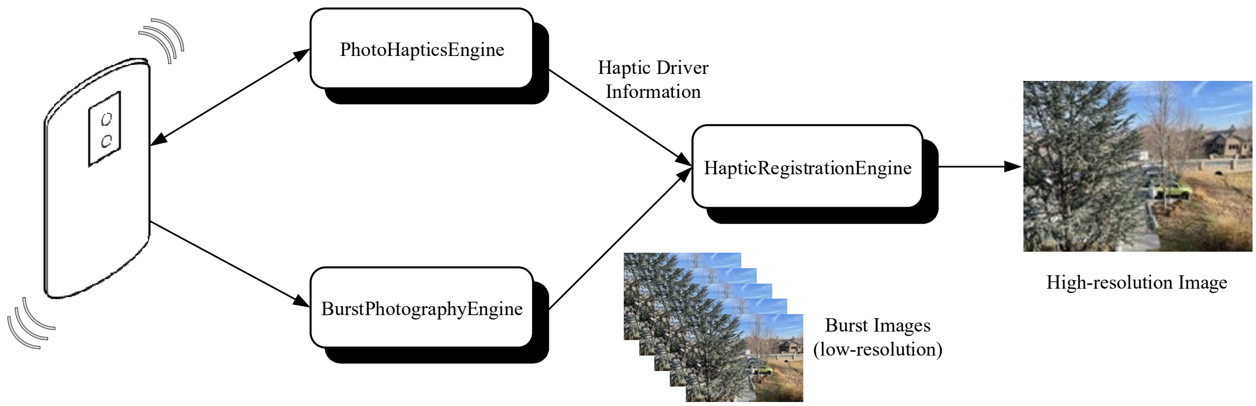

Figure 1

Figure 1 illustrates a schematic representation of an enhanced super-resolution photography technique using haptic motor vibration during burst-mode capture photography to anticipate pixel values for generating a high-resolution image from multiple low-resolution burst images. Upon receiving user input (e.g., a user selecting to capture an image on their smartphone), a PhotoHapticsEngine (e.g., haptic manager) located on a computer-readable medium within the smartphone sends haptic driver information to a processor on the smartphone. The processor then sends instructions to a haptic actuator on the smartphone to execute a haptic pattern resulting in subtle vibration of the smartphone in a particular sequence.

Contemporaneously with the vibration, a BurstPhotographyEngine (e.g., burst photography manager) located on a computer-readable medium within the smartphone sends instructions to a processor to capture a burst of multiple low-resolution images utilizing a camera of the smartphone. The vibration of the smartphone during burst-mode image capture generates sub-pixel shifts among the multiple low-resolution images. A HapticRegistrationEngine (e.g., enhanced super-resolution manager) subsequently processes the multiple low-resolution images using prior information of the vibration pattern with enhanced super-resolution techniques to anticipate pixel shifts and produce a single high-resolution image.

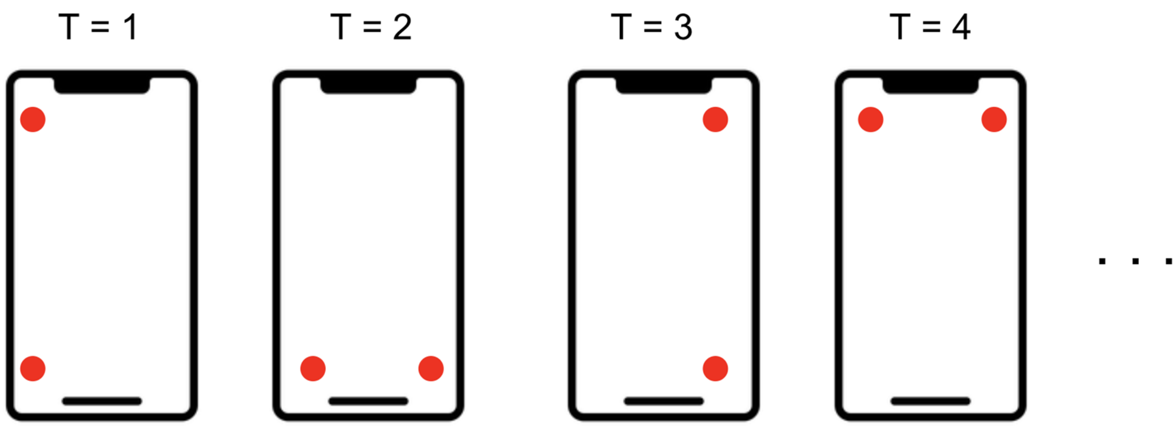

Figure 2

An example of a haptic pattern is shown in Figure 2. The PhotoHapticsEngine activates a set of haptic motors located in the corners of a smartphone in a spatially diverse way (east → south → west → north) at progressive time intervals (e.g., T=1 at one second, T=2 at two seconds, T=3 at three seconds, T=4 at four seconds). In aspects, smartphone models with multiple haptic motors produce distinct haptic patterns corresponding to a pre-programmed unique vibration code. The unique vibration code is associated with instructions for compensating for the slight pixel shift during super-resolution image processing. In other aspects, smartphone models with a single motor may implement a "blind" version of random-motion-aided photography where the haptic pattern is unknown.

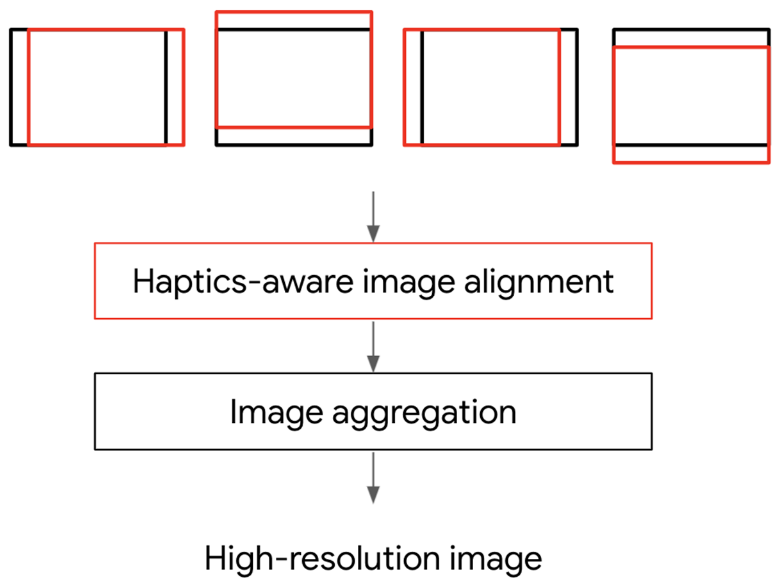

Figure 3

Figure 3 illustrates a process for using prior information of a haptic pattern (e.g., a unique vibration code) to implement haptic-aware image alignment in producing a high-resolution image using enhanced super-resolution techniques. Sub-pixel shifts occur during burst-mode capture resulting from a smartphone haptics motor moving a camera in a particular haptic pattern while capturing multiple images. Information of the haptic pattern may be subsequently used to compensate for the sub-pixel shifts during image processing to increase the resolution for a single image with increased resolution. Prior information of the haptic pattern solves the problem of having an algorithm make assumptions regarding the magnitude of sub-pixel shifts resulting in poor image quality. The HapticRegistrationEngine utilizes prior information (e.g., haptic pattern, timestamps) for driving the haptic motors during each image capture. Enhanced super-resolution uses prior information of the haptic motor vibration during burst-mode capture. The prior information includes information regarding anticipated sub-pixel shifts which can be used for aligning the images. After precise alignment and aggregation of the multiple images has occurred, an image with increased resolution is produced.

In conclusion, enhanced super-resolution photography using haptic motor vibration during burst-mode capture on smartphones provides a novel framework that generates sub-pixel shifts in burst-mode capture photography by activating a smartphone haptic motor during a photo-taking session. The haptic motor vibrates the smartphone thereby replacing natural user hand movement cues traditionally used in creating a high-resolution photo. Prior information of the sub-pixel shift among direction created by the haptic pattern allows an algorithm to accurately anticipate pixel values and generate a single image of increased resolution from multiple low-resolution burst images. In aspects, the vibration driven by the haptic motor may be device-controlled in order to ensure the correct amount of movement necessary for creation of a high-resolution photo.

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