# Supplementary Material: M-GAID: A Real-World Dataset for Ghosting Artifact Detection and Removal in Mobile Imaging

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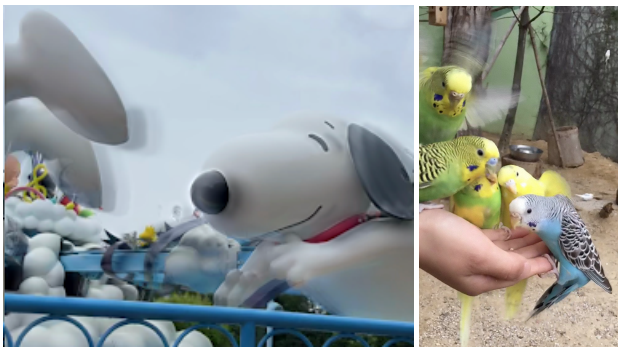
## 1. Introduction

The Mobile Ghosting Artifact Imaging Dataset (M-GAID) is a meticulously curated dataset developed to address the unique challenges of ghosting artifact detection and removal in mobile imaging. It consists of 87 diverse real-world scenarios, designed to capture a range of motion dynamics, lighting variations, and scene complexities (as shown in Figure 1). M-GAID replicates the challenges faced in mobile photography, offering a robust platform for testing algorithms under real-world conditions.

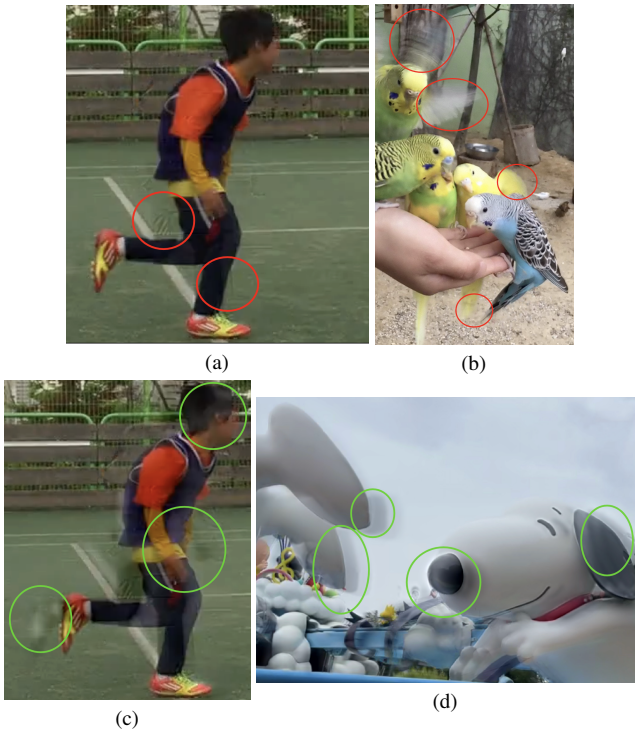


(a) (b)

Figure 1. Examples of M-GAID dataset illustrating ghosting artifacts in outdoor real-life dynamic scenarios.

Ghosting artifacts, caused by motion misalignment during multi-frame fusion, are prevalent in mobile imaging due to lower bit depth (8- or 10-bit) compared to DSLR cameras (14-bit). These artifacts are classified into high-frequency artifacts, affecting fine details (as shown in Figure 2a and 2b), and low-frequency artifacts, impacting smoother regions (as shown in Figure 2d and 2c). M-GAID provides 2,520 images annotated at the patch level (224×224 pixels) to facilitate precise evaluation.

M-GAID aims to address the limitations of existing datasets, which predominantly focus on DSLR imagery and fail to address the unique challenges posed by mobile imaging, such as higher noise levels, lower dynamic range, and real-world scene complexities. By providing a detailed, patch-based, and mobile-focused dataset, M-GAID serves as a critical resource for advancing the development and evaluation of algorithms aimed at improving mobile image quality, particularly in detecting and mitigating ghosting artifacts under diverse conditions.



(a) (b) (c) (d)

Figure 2. Figures 2a and 2b illustrate high-frequency (red circles) ghosting artifacts instances while Figures 2d and 2c illustrate low-frequency (green circles) instances. Understanding the distinction between these artifacts is crucial for assessing the variety and complexity of ghosting artifacts encountered in different scenarios.

| Dataset | Source Device | Image Resolution | Lighting Conditions | Number of Images | Ground Truth | Artifact Type |
|---|---|---|---|---|---|---|
| M-GAID | Apple iPhone 6<br>Apple iPhone 7 Plus<br>Apple iPhone XS<br>Apple iPhone 11<br>Apple iPhone 13 mini<br>Apple iPhone 14 Pro<br>Galaxy S20+<br>GoPro | 720×960<br>720×1280<br>960×720<br>1080×1440<br>1080×1920<br>1280×720<br>1440×1080<br>1920×1080 | Day/Night | 2,520 | Yes | - High & Low Frequency<br>- Misalignment Ghosting<br>- Color Artifacts<br>- Blurring<br>- Frame Wobble<br>- Frame Jitter |

Table 1. Overview of the M-GAID dataset, including source devices, image resolutions, lighting conditions, number of images, and artifact details.

## 2. Patch Labeling System

To ensure detailed evaluation, the M-GAID dataset uses a patch labeling system. Each image is divided into 224×224 pixel patches, enabling localized detection of ghosting artifacts. Each patch is labeled on a scale from 0 to 5 (as shown in Figure 3), with 0 indicating no artifact and 5 representing severe ghosting. This fine-grained labeling allows for a more nuanced analysis of artifacts, which is crucial for training machine learning models.

## 3. Dataset Collection Methodology

### 3.1. Equipment and Setup

The M-GAID dataset was captured using eight mobile and hand-held devices, ensuring diversity in image quality and sensor characteristics (as shown in Table 1). Images and videos were recorded under various conditions, including HDR, low-light, and motion-based scenarios. While resolution and bit depth were standardized where possible, variations were introduced to simulate real-world use cases.

### 3.2. Environmental Conditions

The data collection process covered a wide range of environmental conditions, including different lighting scenarios (outdoor, indoor, HDR) and motion dynamics (static, minor shakes, rotational motion). This ensures that the dataset comprehensively reflects the varied challenges encountered in mobile imaging.

Table 2 summarizes the comprehensive range of scenarios and conditins covered in the M-GAID dataset. Each scenario is categorized by specific motion conditions, illumination conditions, and scene conditions, providing a clear and organized overview of the dataset's extensive coverage.

### 3.3. Challenges in Data Collection

While developing the dataset, significant challenges included ensuring consistency in lighting and motion conditions and capturing realistic ghosting artifacts across different scenarios. Variability in mobile camera performance due to changing environmental factors added complexity, which was accounted for during annotation.

## 4. Annotation Process and Tooling

### 4.1. Annotation Tools

We employed a team of 20 annotators to manually annotate and label the ghosting artifacts at the patch level. 5 expert reviewers thoroughly reviewed and validated the annotations to ensure accuracy, particularly for subtle artifacts that automated systems might miss. The grid-based labeling system (as shown in Figure 3) allowed for precise localization of ghosting artifacts.

### 4.2. Inter-Annotator Agreement

We conducted training sessions to ensure consistency across annotators. This helped align the labeling criteria and ensured uniformity in the dataset annotations.

### 4.3. Annotator Variability and Dataset Clustering

Due to the inherent variations in artifact labeling among our dataset annotators, it is possible to create distinctive clusters of the dataset, where each cluster represents annotations from different individuals. In this case, we can preserve each dataset from each labeler by not aggregating them into one. This approach would result in multiple datasets reflecting multiple user perspectives, enabling the analysis of annotator-specific characteristics and their impact on model performance.

## 5. Dataset Splits and Availability

### 5.1. Dataset Structure

The M-GAID dataset is organized into separate folders for high-frequency and low-frequency ghosting artifacts. For each category, the dataset contains two folders (Original

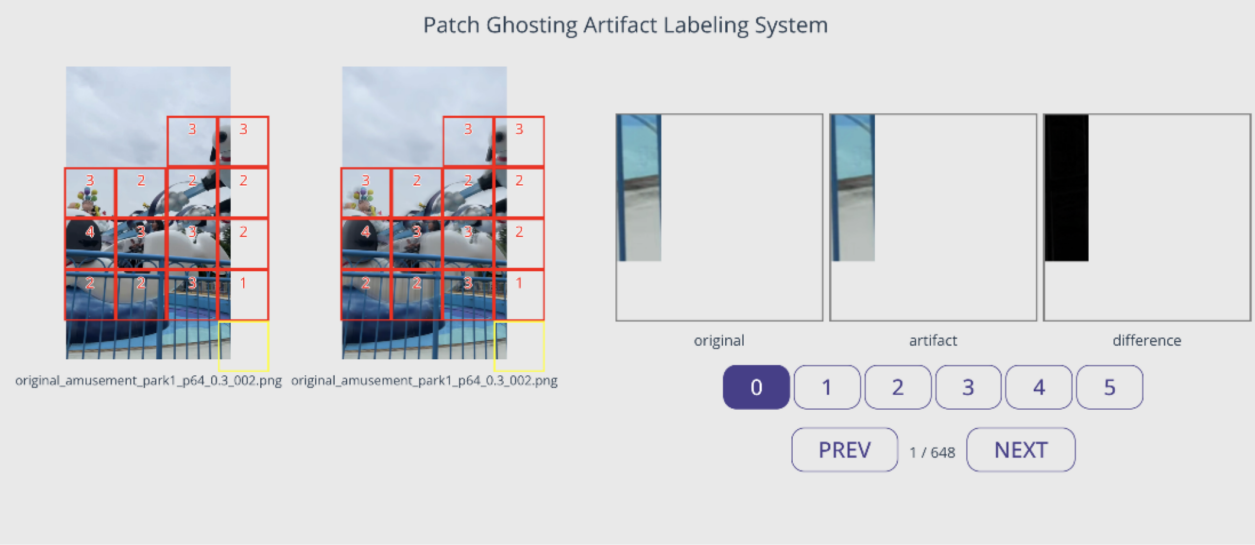



Figure 3. Patch Ghosting Artifact Labeling System: The left panel displays the original and denoised images with a grid overlay for detailed artifact localization. The right panel shows a patch-based view of the selected original image, highlighting artifact-affected patches along with their corresponding difference maps.

images without ghosting artifacts and denoised images with ghosting artifacts). Additionally, two CSV files are provided:

- **Classification CSV:** This file contains classification labels for each image, indicating whether it has ghosting artifacts.
- **Severity CSV:** This file assigns a severity score (on a scale of 0 to 5) for each ghosting artifact in the images, offering more granular information on the extent of the artifacts.

Although predefined training, validation, and test splits are not provided, users can create custom splits based on their research needs. This allows for flexibility in evaluating different aspects of ghosting artifact detection and removal.

### 5.2. Dataset Availability

The M-GAID dataset has been made publicly available to facilitate research on ghosting artifact detection and removal in mobile imaging. It consists of two subsets categorized based on their frequency characteristics:

- M-GAID High-Frequency Dataset [1]
- M-GAID Low-Frequency Dataset [2]

[1]Accessible at: https://pilab.smu.ac.kr/datasets/m-gaid-high-frequency-dataset

[2]Accessible at: https://pilab.smu.ac.kr/datasets/m-gaid-low-frequency-dataset

## 6. Limitations of the Dataset

While M-GAID captures a broad range of real-world scenarios using various mobile devices, some limitations remain. The dataset includes images captured on devices such as the Apple iPhone 6, iPhone 7 Plus, iPhone XS, iPhone 11, iPhone 13 Mini, iPhone 14 Pro, Samsung Galaxy S20+, and GoPro, which provide good coverage but do not fully represent the diversity of mobile hardware currently available. Future expansions of M-GAID could benefit from including a wider variety of device types, manufacturers, and models to improve the dataset's generalizability across different mobile platforms.

Additionally, while the dataset covers both day and night conditions and includes various resolutions ranging from 720×960 to 1920×1080, expanding the range of geographic locations and environmental conditions (e.g., extreme low-light scenarios, high-speed motion) would enhance the dataset's robustness. Including more diverse environmental factors would allow for a more comprehensive evaluation of algorithms, especially in more challenging real-world situations.

Moreover, future versions could extend artifact types beyond the current focus on high- and low-frequency ghosting, misalignment, color artifacts, blurring, frame wobble, and jitter to encompass even more complex and subtle artifacts encountered in advanced imaging tasks.

## Appendix

## A. Scenario Breakdown and Environmental Conditions

| Sr. | Category | Motion Conditions | Illumination Conditions | Scene Conditions |
|---|---|---|---|---|
| 1 | Handheld Small Motion | Minor camera shakes | Outdoor Daylight | Animals |
| 2 | Handheld Small Motion | Minor camera shakes | Outdoor Lowlight | Animals |
| 3 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Animals |
| 4 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Similar object colors with backgrounds |
| 5 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Moving person |
| 6 | Handheld Small Motion | Minor camera shakes | Indoor Daylight | Book with text |
| 7 | Handheld Small Motion | Minor camera shakes | Lowlight HDR | Moving light with camera, Hand shaking, Moving person |
| 8 | Handheld Small Motion | Minor camera shakes | Outdoor Daylight | Animals, Moving person |
| 9 | Handheld Small Motion | Minor camera shakes | Indoor Lowlight | Moving lights, Repetitive pattern |
| 10 | Handheld Small Motion | Minor camera shakes | Indoor HDR | Reflectance material, Moving person, Animals |
| 11 | Handheld Small Motion | Minor camera shakes | Indoor HDR | Moving person |
| 12 | Handheld Small Motion | Minor camera shakes | Indoor HDR | Hand shaking, Moving person |
| 13 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Moving person |
| 14 | Handheld Small Motion | Minor camera shakes | Indoor HDR | Moving light with camera, Moving person, Thin line on flat areas |
| 15 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Animals |
| 16 | Handheld Small Motion | Minor camera shakes | Outdoor Daylight | Reflectance material, Moving Person |
| 17 | Handheld Small Motion | Minor camera shakes | Outdoor Daylight | Moving person |

| Sr. | Category | Motion Conditions | Illumination Conditions | Scene Conditions |
|---|---|---|---|---|
| 18 | Handheld Small Motion | Minor camera shakes | Outdoor HDR | Moving person, Rotational motion |
| 19 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | |
| 20 | Panning | Horizontal/Vertical camera movement | Indoor HDR | Reflectance material, Moving person |
| 21 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Moving person |
| 22 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | |
| 23 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | |
| 24 | Panning | Horizontal/Vertical camera movement | Outdoor Lowlight | Lowlight HDR |
| 25 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | |
| 26 | Panning | Horizontal/Vertical camera movement | Indoor HDR | Moving person |
| 27 | Panning | Horizontal/Vertical camera movement | Outdoor Lowlight | Hand shaking, Moving person |
| 28 | Panning | Horizontal/Vertical camera movement | Outdoor Lowlight | Cars, lowlight HDR |
| 29 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | Cars, Moving person |
| 30 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Moving person, Similar object colors with backgrounds |
| 31 | Panning | Horizontal/Vertical camera movement | Outdoor Lowlight | Lowlight HDR |
| 32 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Moving person, Thin object |
| 33 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Cars, Moving person |
| 34 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Moving person |
| 35 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Cars |
| 36 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | Moving person |
| 37 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | Moving person |
| 38 | Panning | Horizontal/Vertical camera movement | Outdoor Daylight | |

| Sr. | Category | Motion Conditions | Illumination Conditions | Scene Conditions |
|---|---|---|---|---|
| 39 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | Reflectance material |
| 40 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | |
| 41 | Panning | Horizontal/Vertical camera movement | Outdoor HDR | Moving person |
| 42 | Static | No motion | Outdoor Daylight | |
| 43 | Static | No motion | Outdoor Lowlight HDR | Moving lights |
| 44 | Static | No motion | Indoor Daylight | |
| 45 | Static | No motion | Outdoor Lowlight | |
| 46 | Static | No motion | Outdoor Daylight | Animals |
| 47 | Static | No motion | Indoor HDR | |
| 48 | Static | No motion | Indoor Daylight | Rotational motion |
| 49 | Static | No motion | Lowlight HDR | Hand shaking, Moving Person |
| 50 | Static | No motion | Lowlight HDR | Hand shaking |
| 51 | Static | No motion | Indoor HDR | Reflectance material, Moving person, Rotational motion |
| 52 | Static | No motion | Lowlight HDR | Indoor HDR, Moving lights |
| 53 | Static | No motion | Lowlight HDR | Outdoor lowlight, Moving lights |
| 54 | Static | No motion | Outdoor lowlight | Lowlight HDR, Moving lights |
| 55 | Static | No motion | Indoor Daylight | Reflectance material, Animals |
| 56 | Static | No motion | Indoor Daylight | Reflectance material, Moving person |
| 57 | Static | No motion | Indoor HDR | Reflectance material, Moving person, Hand shaking |
| 58 | Static | No motion | Indoor Daylight | |
| 59 | Static | No motion | Outdoor Lowlight | Lowlight HDR, moving lights |
| 60 | Static | No motion | Indoor Lowlight | Moving person, Thin object, Moving lights |
| 61 | Static | No motion | Indoor Daylight | Thin object |
| 62 | Static | No motion | Indoor Daylight | |
| 63 | Static | No motion | Indoor Daylight | Reflectance material |

| Sr. | Category | Motion Conditions | Illumination Conditions | Scene Conditions |
|---|---|---|---|---|
| 64 | Static | No motion | Indoor HDR | Reflectance material, Rotational motion |
| 65 | Static | No motion | Outdoor Lowlight | Thin object, Lowlight HDR |
| 66 | Static | No motion | Outdoor Daylight | Moving person, Similar object colors with backgrounds |
| 67 | Static | No motion | Outdoor HDR | Moving person, Rotational motion |
| 68 | Static | No motion | Outdoor Lowlight | Moving person, Rotational motion, Lowlight HDR, Similar object colors with backgrounds |
| 69 | Static | No motion | Indoor Daylight | Moving person, Rotational motion |
| 70 | Static | No motion | Indoor Daylight | Book with text |
| 71 | Static | No motion | Indoor Lowlight | Moving lights |
| 72 | Walking/Running | Continuous movement | Outdoor Daylight | Thin object |
| 73 | Walking/Running | Continuous movement | Outdoor HDR | Moving person |
| 74 | Walking/Running | Continuous movement | Outdoor HDR | Moving person |
| 75 | Walking/Running | Continuous movement | Outdoor Daylight | |
| 76 | Walking/Running | Continuous movement | Outdoor Daylight | Animals |
| 77 | Walking/Running | Continuous movement | Outdoor HDR | Reflectance material, Moving person, Repetitive pattern |
| 78 | Walking/Running | Continuous movement | Outdoor HDR | |
| 79 | Walking/Running | Continuous movement | Indoor HDR | Moving person |
| 80 | Walking/Running | Continuous movement | Outdoor HDR | Repetitive pattern |
| 81 | Walking/Running | Continuous movement | Indoor Daylight | Moving person, Repetitive pattern |
| 82 | Walking/Running | Continuous movement | Outdoor Daylight | Moving person |
| 83 | Walking/Running | Continuous movement | Outdoor HDR | Moving person |
| 84 | Walking/Running | Continuous movement | Indoor Daylight | Moving person |
| 85 | Walking/Running | Continuous movement | Outdoor HDR | Moving person |
| 86 | Walking/Running | Continuous movement | Indoor HDR | Moving person, Repetitive pattern |
| 87 | Walking/Running | Continuous movement | Outdoor HDR | Moving person |