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BouncyPhoton: Exploring Photography through Post-Printed Editing with Implicit Projection Mapping

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Abstract of Master's Thesis of Academic Year 2025

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Summary

Photography is often seen as a fast medium for conveying information, as viewers can quickly grasp the time, place, subject, and story. However, in today's fast-paced culture, people have developed habits of skimming images, even when engaging with photographic art that should be appreciated with attention. As contributors to photo-based media, I identified key challenges in how photography is perceived and presented in physical spaces. I introduce BouncyPhoton, a system that projects visually important elements such as highlights, edges, and texture onto photographs that reacts with the viewers to enhance their visual impact in physical spaces. I call this non- destructive projecting method implicit projection mapping. I discuss how implicit projection mapping can be used not just as a method of augmenting photography, but as a medium to reengage audiences with still imagery in immersive and interactive ways.

Keywords:

Human-computer interaction, projection mapping, pro-cam, visual, media art

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Chapter 1
Introduction

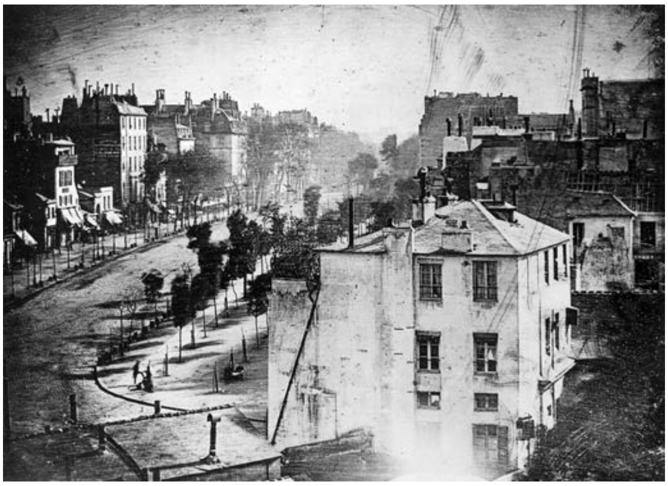


Figure 1.1 Boulevard du Temple
(Source: Boulevard du Temple [1])

1.1. Photography An Aging Media

In 1838, Louis Daguerre captured one of the earliest surviving photographs and it is a significant step in the development of photography [2], titled "Boulevard du Temple"(See Figure 1.1) in Paris, France. While it was not the first photograph ever taken—an achievement credited to Nicéphore Niépce [3] [4] in 1826 or 1827—Daguerre's image was groundbreaking, as it was one of the first to capture a human figure. When he photographed this seemingly deserted street] [4], he may not have imagined how profoundly photography would evolve in the 21st century.

Since then, photography has undergone rapid transformation, from the one-of-a-kind daguerreotype to roll film, and eventually to digital sensors that now exist in everyone's pocket. It is remarkable to see how photography has shifted from a complex, labor-intensive process to an accessible and widely enjoyed activity.

I have a deep love for photo prints, and in many ways, they have shaped my entire life(See figure1.2). Why do I say this? Because my parents ran a photo printing lab. Although today the lab is known as Lijing Photo, it once carried a more iconic name: Kodak Minilab. It was through their dedication to the photo printing business that they supported our family. Printing photos put food on our table, and it was this very profession that gave me the opportunity to travel the world. For me, photography is not only a passion but also a profound source of gratitude that has directly influenced the research I am pursuing today.

1.2. The Unreplaceable Media

In the recent decade, most media content has been consumed digitally. People are used to looking at photos on phones, tablets, or computer screens. While this makes sharing and viewing photos faster and easier, it also changes the way we interact with photography. Many images are now viewed quickly, skipped, or forgotten in cloud storage. [5].

However, printed photography still holds a special meaning. It has a physical presence. The texture of the paper, the color of the ink, and the way light reflects from the surface are things that cannot be felt through a screen. Printed photos invite people to take a closer look. They stay in albums, frames, or on walls [6]. They become part of people's lives and memories. As Sontag (1977) observes, photographs do not merely capture reality, instead they become embedded in the rituals and artifacts of everyday life, certifying and preserving our experiences [7].

Printed photos are also more than just visual records. They are connected to emotions, places, and stories. Unlike digital files that can be deleted or lost, prints often survive over time. Even old photos in a dusty box can bring back memories when found again. This is why printed photography is still meaningful, and why I believe it should not be replaced, but reactivated through new ways of interaction. In this research, I aim to bring attention back to printed photography

Figure 1.2 Left: Author's father holding the 4 years old author. Right: Author's father when he was 4 years old

using projection. By adding light-based interaction, I hope to make people spend more time with printed photos, and to see them in new ways without losing their physical charm.

1.3. Restore/Revive/Reactivate Photography

In today's world, photography is everywhere. People take more photos than ever before, but spend less time with each one. Many images are quickly taken and quickly forgotten, lost in the flood of digital content. Even in exhibitions, visitors often glance at photographs without truly engaging with them. The deep, contemplative attention that once existed between the viewer and the printed photograph is slowly disappearing.

This research aims to restore that connection. The goal is to bring attention back to printed photography—not by replacing it, but by adding a new layer of interaction. I want to revive the experience of looking at a photo slowly, carefully, and with emotion. I call this approach "post-printed editing." It does not change the print itself, but adds light-based edits through projection that highlight or reshape parts of the image in real time.

The idea is to make printed photography feel more alive and more reactive. Viewers can see changes in light, texture, or tone as they move around or stand in front of the photo. Their presence becomes part of the photo experience. This interaction invites them to stay longer, look deeper, and feel more connected to what they see.

The main research question of this thesis is: How can projection-based interaction help people reengage with printed photography in physical space?

This question guides the design of BouncyPhoton, a system that combines physical prints with computational projection to create a new way of seeing.

1.4. Structure

This thesis consists of six chapters. Chapter 1 provides the background and motivation for this research by examining how printed photography has gradually lost attention in the digital age, and introduces the idea of restoring its relevance through projection-based interaction. Chapter 2 reviews related works across photography theory, visual media technology, and projection mapping, identifying key methods and concepts that inform the system design. Chapter 3 presents the development of the BouncyPhoton system, beginning with personal observations, early prototyping, and the conceptual decisions made through iterative design. Chapter 4 introduces the proof of concept, showcasing the exhibition setup, the viewer experience, and the resulting qualitative insights. Chapter 5 discusses the overall findings, limitations, and possible applications beyond the gallery context. Finally, Chapter 6 concludes the thesis by summarizing the contributions and suggesting future directions for research and refinement.

Chapter 2
Literature Reviews

2.1. The concept of Printed Photography

Photography, the act of "writing the light" has at least 150 years of history [8]. And printed photography is more than just a record of people, places or events, it is a physical object with cultural, material, and communicative significance [9]. Across many cultures, printed photographs have long played a role in preserving memory, expressing emotion, and fostering personal connection. Their presence on walls , in albums or as gifts reflects how they anchor social rituals and family heritage. Unlike it digital counterpart, printed photos demand stillness and close attention. Their medium: texture, scale, and permanence shapes how they are seen and felt. As both a tactile object and communicative gesture, printed photography continues to hold an unique place in contemporary visual culture.

2.1.1 Printed photography as a Culture

Printed photographs have long played important roles in shaping personal and cultural memory [10]. In many households, like mine, printed photographs are more than just images, they are part of daily life. They are placed on the wall, kept in albums, stored in drawers, and passed from one generation to another. These physical objects carry emotional weight and serve as visual anchor for remembering people, places and stories.

In the introduction, I mentioned that my parents ran a photo printing shop that used to be called Kodak Minilab shop. Here, I would like to expand on the history of Kodak and how it helped transform printing photography from a highly specialized skill into a cultural practice. A key historical moment that allowed printed photography to become deeply embedded in everyday life was Kodak's introduction of the roll-film camera in 1888 [4]. As Munir and Phillips (2005) point out, Kodak used advertising strategies and product design to shift photography from a professional pursuit to a popular, everyday activity. They specifically targeted families, women, and children, successfully linking photography to life rituals such as travel, celebration, and memory. Through slogans like the "Kodak Moment," Kodak helped cultivate photo printing as a cultural habit rather than merely a functional task [11]. Even though Kodak sadly missed the digital transformation in the early 2000s [12], it still managed to play a defining role in making printed photography a meaningful cultural practice.

Researchers such as Geoffrey Batchen and Roland Barthes have reflected on the cultural meaning of printed photographs. Batchen noted that prints often function as ritual objects, used in memorials, shrines, or family storytelling [9]. Barthes introduced the idea of the punctum—a small detail in a photograph that "pierces" the viewer emotionally, often because of its personal relevance [13]. Both authors highlight the power of the printed photo to create meaning beyond the image itself.

In many cultures, printed photos are still involved in rituals of memory and belonging. They are used to mourn, celebrate, and document shared experiences. Even as digital photography has become dominant, the printed photograph continues to carry cultural presence in a way that screen-based images often do not. This cultural foundation makes printed photography a valuable medium to revisit and rethink in contemporary design.

2.1.2 Printed Photograph as A Medium

Even though digital and printed photographs often display the same visual content, they are experienced very differently. This is because the medium through which a photo is encountered shapes how it is interpreted. As Marshall McLuhan famously argued:"the medium is the message" [14]. In other words, it is not just the content that matters, but the form in which it is delivered. A photograph seen on a glowing phone screen invites rapid scrolling and multitasking, and even short attention on the content nor the medium. In contrary, a printed photograph, asks for stillness. It becomes a physical presence in space, a object that can be held, framed or passed between hands. In understanding media, McLuhan describes media as extension of the human body and mind, it is technologies that reshape how we perceive and act [15]. A printed photo is not simply a passive object, but an tangible interface. Its paper texture, scale, and permanence all contribute to how viewers relates to the image and the memory it represents. Research from University of Aberdeen shows that texture affects visual perception and emotional engagement. For example, smoothness make images feel soft and intimate, while rough or textured surfaces can evoke depth, tactility and material presence [16]. By acknowledging photography as a medium, not just as an image. I can better understand how its printed form communicates differently from its digital version. Furthermore, the physical surface of printed photography plays a critical role in how it is visually perceived. According to Farnood, "gloss is a psychophysical property that significantly influences the visual perception of the observer." [17] In other words, how light reflects off the surface whether softly from matte paper or sharply from a glossy finish directly affects how an image is experienced.

2.1.3 Printed photograph as Communication Method

Since the birth of visual media, they have been the center of sharing. From paintings to photographs. They are created to be shared among people. As Kevin Moore said :"Photograph is essentially an act of sharing. Photographer discover in the finder of their cameras something so needed that they often end up giving prints away" in the book proof of color [18]. This capture the unique social nature of photography, not just as a record of seeing, but as a gesture of giving, The act of printing a photograph carries with it the intention of communication: To pass along an emotion, am merry or a perspective. This was shown best in a gallery, exhibition and museum. People visit them to receive the messages. Printed photographs in particular embody his function. Unlike digital files that remain trapped in personal devices, prints are made to circulate. They can be gifted, mailed, or turned in to books. They take up physical spaces in people's rooms. They speak across time and space. In this way photography becomes not just a tool for recording and documentation, but a medium or sharing.

2.2. Visual Media Enhancing Technologies

Printed visual art has always strived to capture the attention of its viewers, a goal that has remained constant over time. Since the advent of electricity, artists have explored new ways to make their work more engaging, using light, screens, and projection to make their creations stand out. These experiments gave rise to new forms of media—some call them installation art, others refer to them as new media. In my research, however, I aim to shift the focus back to the original purpose of these attention-grabbing tools: to support the artwork rather than replace it. In this case, printed photography remains the central subject. In this section, I review the work of pioneering researchers in the field. By analyzing their approaches, I hope to draw inspiration and borrow effective techniques to further develop my own system.

2.2.1 Using Projection Mapping as An Attention Grabbing Method.

Many past research projects have explored how to bring new life to printed media by adding interactive or dynamic features. These projects often aim to make the content more attractive by transforming it into something that moves, responds, or surprises the viewer.

One well-known approach is to make printed images behave like digital content. For example, Ishii et al.'s I/O Brush allowed users to "paint" digital video content onto a canvas using a physical brush [19]. Similarly, DisplayObjects by Poupyrev et al. introduced interactive projections on top of physical surfaces, making printed material appear to animate or respond to touch [20]. These works used projection as a way to merge physical and digital interaction.

In the art world, teamLab installations use projection extensively to bring paintings and drawings to life. Their works often cover walls and floors with colorful, moving projections that respond to the presence of visitors [21]. Although these installations are visually impressive, they often prioritize spectacle and immersion over the subtle appreciation of the original artwork.

In terms of research focused on photographic prints, the Deformation Lamps project by Bermano et al. proposed a method for altering the appearance of static objects using dynamic lighting projection [22]. This technique is highly relevant to this thesis. However, their work focused more on visual illusion and perceptual trickery—making objects appear to move or change shape without any actual motion—rather than deepening attention toward photographic meaning.

While these projects are creative and technically impressive, many of them treat projection as a tool for entertainment or surprise. They often add visual effects on top of the media to capture attention quickly, rather than helping viewers spend more time with the content itself. In contrast, this thesis explores how projection can support a quieter, slower form of interaction. Instead of turning a photo into a video or a game, I aim to use light to reshape visual focus and gently guide the viewer's attention—helping them see printed photography in a new way without changing its original material or meaning.

2.2.2 Photographic Key Feature as Guidance

Some recent studies and media art projects have explored how to enhance printed materials without fully replacing or digitizing them. This direction often focuses on non-destructive augmentation, where the original physical object remains visible and central, while additional content is layered subtly on top through projection or light.

For example, IllumiRoom by Jones et al. (2013) explored how peripheral projection could expand visual space around a screen without distracting from the central content [23]. On the otherhand, LightGuide by Rajinder Sodhil(2015) is a projected guidance system that provides real-time visual hints directly onto the user's body, specifically the hands.It supports mid-air movement tasks such as physical training or rehabilitation. By combining depth sensing and spatially aligned projection, the system provided real-time feedback and feedforward, improving gesture accuracy significantly without the need for external screens. This demonstrated how visual overlays—when registered precisely to physical form—can subtly guide user behavior without being visually intrusive [24].

More directly related to printed images, Deformation Lamps by Bermano (2012) demonstrated how dynamic lighting could visually alter physical surfaces by subtly changing shape or appearance using controlled luminance [22]. Although their focus was on perceptual illusion, their method of relying on light-based manipu-

Figure 2.1 Volkswagen projection mapping on a book

(Source: Volkswagen projection mapping on book Geckow Smarte Mediensysteme Youtube Channel) [25]

lation of specific features is a foundation for this research. Unlike Deformation Lamps, which often prioritize transformation effects, our approach focuses on emphasizing existing photographic elements, like highlights and textures, in ways that support interpretation and engagement.

Material sensitivity is also an important consideration. For example, in 2015, Volkswagen presented a projection mapping experiment onto a real physical book [25]. The system precisely aligned projected content with the surface of turning pages, enhancing the reading experience while preserving the tactile qualities of paper. This example reflects the growing interest in integrating projection with real-world materials in a way that maintains their physical and sensory integrity(See figure2.1).

These prior works show that selective, non-invasive projection can be a powerful tool for interaction and attention design. However, most of them focus on functional guidance, animation, or perceptual illusions. In this research, I extend this idea to photographic appreciation—using projection not to impress or inform, but to quietly guide attention to meaningful features already present in the printed photo.

2.3. Application of Projection Mapping Practices

Since projection mapping is the primary method used in this research, I reviewed relevant works that explore how projected light can enhance or alter the perception of physical surfaces. Two studies stood out for their influence and relevance. The first is Deformation Lamps by Bermano [22], a project developed at NTT Communication Science Laboratories. This system projects dynamic luminance patterns onto static objects to create the illusion of motion or deformation without altering the object itself. The second study, Dynamic Multi-Projection Mapping Based on Parallel Intensity Control by Mitsumoto from Tokyo Institute of Technology [26], demonstrates a technique for blending light from multiple projectors while maintaining consistent image quality. This approach enables fine-tuned projection on complex surfaces and helps establish stable brightness and clarity in challenging environments.

2.3.1 Projection Mapping that Changes the Contents

The Deformation Lamps project by Bermano et al. (2012) is one of the most influential works related to light-based augmentation of static imagery (See figure 2.2). By projecting dynamically controlled luminance patterns onto physical objects, the system creates the illusion of movement or shape transformation without altering the object itself. [22] This technique leverages human visual perception to introduce animation purely through light.

While the original purpose of Deformation Lamps was to create perceptual trickery such as simulated motion or deformation, it demonstrated the precision and subtlety possible with projection mapping on textured surfaces. This research draws from the same foundational method but applies it toward a different goal: rather than surprising the viewer, projection is used here to quietly guide attention to photographic key features such as highlights, shadows, and texture.

2.3.2 Multi Projection Mapping on 3D Object

The study Dynamic Multi-Projection Mapping Based on Parallel Intensity Control by Mitsumoto et al. (2021) explores a method for controlling overlapping

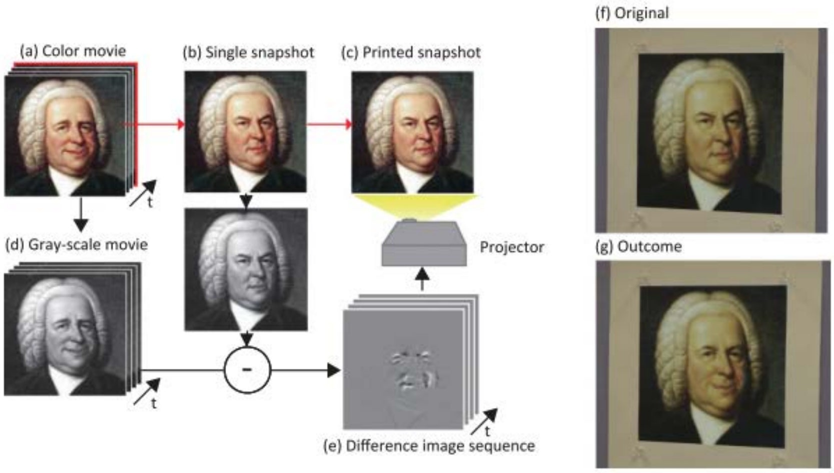


Figure 2.2 Deformation lamp

(Source: Deformation lamps) [22]

projections from multiple projectors (See figure2.3). By adjusting intensity in parallel, the system maintains consistent brightness and sharpness across complex surfaces [26]. This technique enables smooth projection blending and precise visual effects, even in challenging geometric or environmental conditions.

Although the research focuses on spatial control and hardware-level synchronization, its contribution is especially relevant to the current study. When working with printed media, light accuracy is critical. Even small shifts in luminance or alignment can break the illusion of integration between the projected image and the printed surface. The parallel intensity method shows how computational calibration can enhance stability and fidelity in projection environments. This technical insight supports future expansion of BouncyPhoton toward multi-projector setups or more complex print arrangements.

2.4. The Cognitive Science of Attention

In the previous two sections, I explored the history of photography, the role of printed media in society, and how technology has been used to enhance visual media. In this next section, I shift focus to another essential part of my research: how to capture and guide attention. After all, at the core of my system's purpose

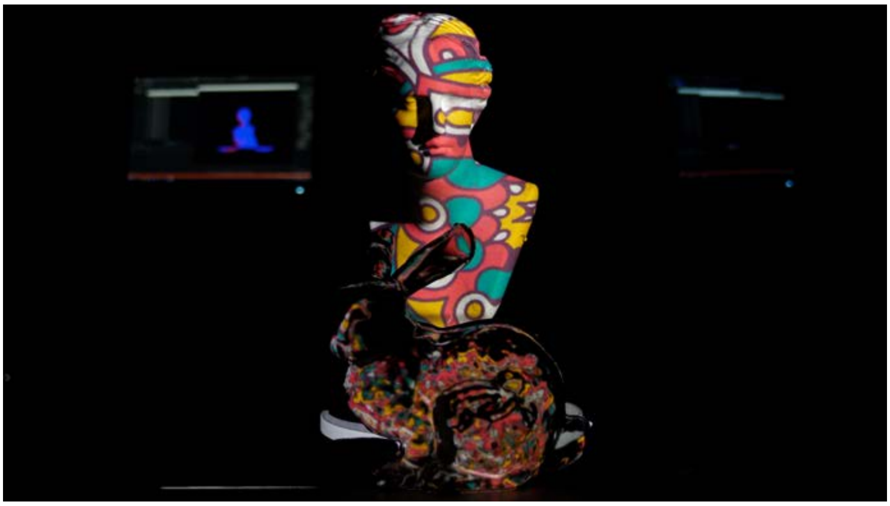


Figure 2.3 Dynamic multi-projection mapping based on parallel intensity control

(Source: Dynamic multi-projection mapping based on parallel intensity control.) [26]

is the ability to hold the viewer's attention. This is not a purely technical concern, attention has long been tied to deeper questions about how we perceive the world. As David C. Lindberg said in his book *Theories of Vision*, the study of vision has never been a narrow technical discipline. Instead, it has always been closely linked to philosophical inquiries about the nature of reality [27]. In this section, I will explore how attention works, both psychologically and visually, and how it has been studied in the context of media, perception, and interaction.

2.4.1 Change Blindness and Selective Attention

One frequently discussed concept in visual perception is change blindness, a phenomenon where observers fail to notice large changes in a visual scene, especially when the change occurs during a brief disruption like a blink, eye movement, or scene cut. As Simons and Levin (1997) describe, "people are blind to changes occurring in photographs, in motion pictures and even in real-world interactions [28]." This highlights how surprisingly little visual information we retain from one moment to the next.

One of the most well-known demonstrations of change blindness is the "invisible gorilla" experiment(See figure2.4), where participants focused on counting basketball passes often fail to notice a person in a gorilla suit walking through the scene [29]. This experiment illustrates how intense focus on one task can reduce our ability to detect unexpected changes in our surroundings. Similarly, Steinicke et al. (2010) showed that change blindness can also happen in immersive 3D environments. Even when big changes happen, like moving or removing objects in stereoscopic projections, people often do not notice them unless they are already paying attention to that part of the scene. [30] Simons and Levin emphasize that

Figure 2.4 Selective attention test video from Daniel Simons's YouTube Channel

(Source: Daniel Simons.2025-06-17) [31]

change detection requires attention, but attention alone is not enough. "Changes to central objects are more likely to be detected, but they are not detected automatically." This suggests that our brains prioritize the gist of the scene over exact details. In the context of media design or interactive installations, this opens up the possibility of subtly guiding attention using non-intrusive visual cues—just as my BouncyPhoton system aims to do through projection mapping that gently emphasizes photographic features without changing the image itself.

Chapter 3

BouncyPhoton System Concept Design

In this chapter, I will explain the design concept behind BouncyPhoton. My process of developing the BouncyPhoton system can be divided into five main phases. It began with FlipGIF(See figure 3.1) as the primary inspiration, followed by early experiments using glass patterns. In the third phase, I explored motion and texture as methods for guiding attention. The fourth phase involved scaling these tests onto larger surfaces, and finally, the fifth phase tested the integrated system within a real exhibition environment. The road was filled with challenges and effort, but also curiosity and excitement.

3.1. From photography Critique to Exhibition

When I first started thinking about this design, I immediately recalled my undergraduate days at the Rochester Institute of Technology. Whenever we submitted photo assignments or presentations, we never did it digitally. Every photo had to be printed on dedicated paper. Then, we had something called a critique. During these sessions, we were given time to view each other's work closely. We could touch the prints, examine the details, and take our time. That experience created space for deep understanding and thoughtful feedback.

This physical interaction with printed photography shaped how I view photographs. It felt very different from most photographic exhibitions, where visitors are often forced to view works from a distance, separated by gallery etiquette. When I visit photo exhibitions now, I always feel the urge to walk closer—to inspect the texture of the paper, the choice of material, and the lighting. These tactile and visual details carry meaning, but they are often overlooked. This early memory planted the seed for what would become BouncyPhoton.

3.1.1 Observations with Current Photo Exhibitions

This physical interaction with printed photography shaped how I view photographs. It felt very different from most photographic exhibitions, where visitors are often forced to view works from a distance, separated by gallery etiquette. When I visit photo exhibitions now, I always feel the urge to walk closer to inspect the texture of the paper, the choice of material, and the lighting. These tactile and visual details carry meaning, but they are often overlooked.

So during my time in the United States and Japan, I visited many photography exhibitions. In almost all of them, visitors are required to maintain a certain distance from the prints. Even though I understand the reasons behind these rules, such as preservation and respect for the artwork. I still believe they limit the audience's experience. In most exhibitions, the only thing a viewer can rely on is visual information. But when you hold a family photo in your hand, your hand and your eyes work together to absorb details like the weight, the texture, the shadows.

This contrast made me wonder: what if we could compensate for the lack of touch using another non-destructive method? Could we use light itself to bring back some of the depth and emotional quality that is lost when viewers are kept at a distance? This idea became one of the starting points for the BouncyPhoton system.

3.1.2 Previous Project with Projection on Top of Photography

This idea also started to take shape during my time at the Rochester Institute of Technology. In a class called Visual Media, I created a project called "FlipGif" (See figure 3.1) that explored the blending of digital projection and printed photography. For this project, I first photographed a series of about 500 images. I printed all of them at a local CVS photo lab, treating them like physical data points. I then imported the same digital images into my computer and collaborated with a computer engineering student from the University of Rochester to

Figure 3.1 FlipGif

(2017ImagineRIT project flipgif by Kanghong Zhong) [32]

develop a custom software tool.

The software was designed to project the original digital images back onto their corresponding printed versions. During the installation, the printed photos were laid out beneath a ceiling-mounted projector. As the software cycled through the images, each print was illuminated with its matching digital version. The projection was carefully aligned, creating a seamless overlay that made the photographs appear as though they were subtly pulsing, shifting, or being reanimated. The prints themselves were never touched or altered—the transformation occurred entirely through light.

This hybrid presentation allowed the viewer to engage with the tactile reality of the printed photo while experiencing it in an enhanced, time-based form. It became my first experiment in using projection not just as a display method, but as a way to reinterpret and reframe printed photography—an idea that would later influence the development of BouncyPhoton.

3.2. Trying to Guide People's Attention Back

As I mentioned in my introduction, people's attention are constantly distracted [33], as the result, one of my mission is to bring people's attention back to the

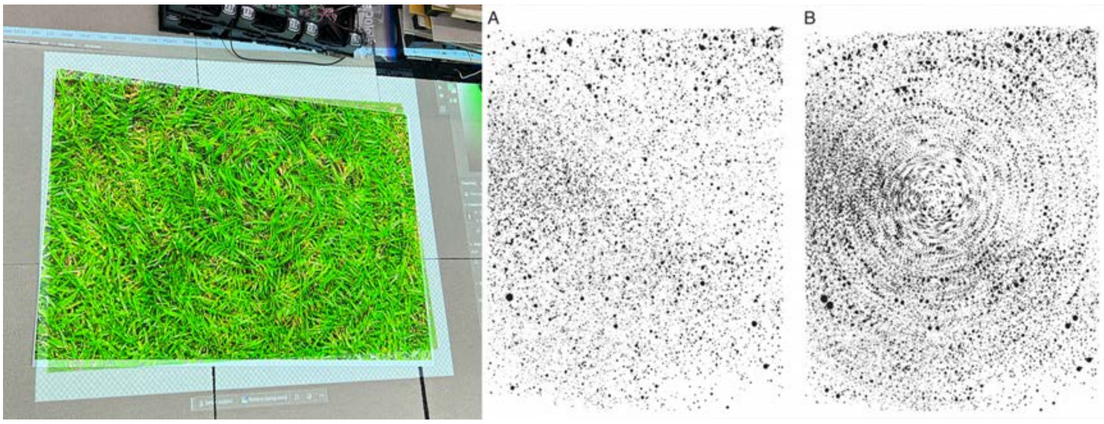


Figure 3.2 Glasspattern

(Source: glasspattern) [34]

printed photography. And I plan to use methods that will not alter the core detail, characteristic and message of the original printed photo, and in photographic term we say: non-destructive editing. Projection is one of those non-destructive way. Projection mapping has been used in many systems to make printed media interactive or visually dynamic. However, most of these systems add visible content on top of the original image, which can distract from or replace the printed material.

Printed photography already has visual value through its composition, texture, and tone. But in current projection-based systems, these features are often overwritten rather than supported.

In this research, we aim to create a non-destructive projection mapping system that enhances printed photos in a subtle way. Instead of replacing the image, we highlight important features like light and texture through implicit projection. Our goal is to bring attention back to printed photography without changing its original form.

3.2.1 Using Glass Pattern

In the early stage of this project, I explored how projection could guide attention to specific areas of a printed photo. One of the first visual elements I tested was the glass pattern, a well-known stimulus in vision science used to study global form perception (See B in figure 3.2). A glass pattern is created by duplicating and rotating dot pairs, which forms circular or spiral structures that are known to catch the viewer's attention.

I generated several types of glass patterns in TouchDesigner and projected them over printed photographs. The goal was to use the pattern as a gentle way to pull attention toward certain parts of the image, without using direct arrows or highlights. I also experimented with different parameters such as dot density, contrast, and motion speed to see which variations felt the most natural when projected onto a matte photo surface.

However, in most tests, the projected pattern stood out too much. Even with low contrast, the pattern tended to become the main focus rather than supporting the printed image. Viewers noticed the visual effect, but often missed the actual content of the photograph. This made it clear that simply adding visual motion or structure would not be enough to create a meaningful connection with the printed photo.

Through these experiments, I began to understand the risk of overpowering the photo with projection. While the glass pattern could attract attention, it also introduced a separate visual layer that competed with the original image. This experience led to the decision to move away from clear, visible patterns and toward more implicit, feature-based augmentation, which I explore in the next section.

3.2.2 Preliminary Study: Find the Difference Game

After realizing that strong visual patterns like glass patterns were too dominant, I started looking for ways to test more subtle forms of projection. I wanted to know whether light-based changes could still influence how people look at a photo without adding obvious digital elements.

To test this, I designed a "find the difference" game using TouchDesigner [35]. In this test, I took two similar versions of a printed photo: one was the original, and the other had a small visual change, such as a slightly brighter region, a soft added texture, or a local tone adjustment. I then projected only the "difference layer" onto the original printed photo, using alignment from a webcam to match the projection with the photo precisely(See figure 3.3).

Figure 3.3 Find the growing colored spot

(Game: Find the growing colored spot) [35]

Participants were asked to observe the printed photo under different conditions with and without projection and try to spot what had changed (See figure 3.4). Each test was time-limited, and I recorded how long it took participants to find the change, or if they noticed it at all. I also observed whether the projection made the change feel natural or distracting.

From this experiment, I found that many participants were able to detect the target area more quickly when the projection was active. In some cases, they described the enhanced photo as "clearer" or "more detailed," even if they couldn't say exactly what had changed. These results suggested that projection could guide visual attention in a subtle and supportive way, without adding bold effects or visible graphics.

This test helped define the direction for the final system. Instead of overlaying new content, the projection would only reveal or amplify features that already exist in the printed photo. The projection became not a layer on top of the photo, but a tool to shift how the viewer sees what is already there.

Figure 3.4 Game: Find the growing colored spot in five different stage

(Game: Find the growing colored spot in five different stage) [35]

3.2.3 Using Motion

After working with glass pattern based attention cues in the VRSJ 2024 study, I realized that projection should serve as the primary medium for this system. To explore how motion might help attract attention, I conducted an early-stage experiment using animated edges derived from found emakimono (traditional Japanese scrolls). These animations were projected directly onto the physical scrolls, and users could control the motion by moving the mouse. This experiment was showcased at the KMD Forum 2024 as a preliminary exploration into how motion, layered through projection, might subtly guide viewers' focus in printed visual media(See figure 3.5).

Building on the idea of using projection to gently guide attention, I explored the potential of animated overlays, such as shifting patterns and soft color transitions, projected onto printed photographs. These elements were designed not to dominate the visual field, but to subtly influence how viewers perceive depth, contrast, or visual flow across the image. The aim was to create a quiet sense of motion that could keep the viewer engaged with the photograph for a longer duration.

Through this phase, I also began to understand the need for balance. While motion can effectively draw attention, excessive movement or overly strong visuals run the risk of overshadowing the printed content. These early experiments helped me reflect on how projection can function as a supportive layer—guiding attention

Figure 3.5 Left: With the texture Projected on the Emakimono. Right: The original Emakimono

without interfering with the original material presence of the photograph.

3.2.4 Making the Projection Non-Destuctive

However, after testing these ideas, I realized that strong motion or clear overlays often made the projection feel too digital. In some cases, the original image became harder to see or lost its meaning. I also noticed that many existing systems in media art and HCI used similar approaches, showing animations or effects on top of paper, often turning the surface into a screen.

To avoid repeating these patterns, I decided to shift toward implicit projection. This means that the projection would not add obvious content but instead use light to support the original image quietly. For example, I began to experiment with projecting just the highlights, textures, or tonal shifts of a printed photo. These small visual changes could influence how people look at the photo without disturbing its physical presence.

3.2.5 Add Interactions

After this shift, I still felt something was missing. The projection helped make the photo more engaging, but it was still a one-way experience. That is when I began exploring audience interaction.

I added a Kinect camera to detect the viewer's silhouette(See figure 3.6). By

Figure 3.6 The shadow of the hand showing in the projection

using the viewer's body position, I could change how the projection appears. In some cases, the projection follows the viewer's presence. In other cases, the viewer's silhouette blocks parts of the projection, making it feel like they are part of the image.

This created a sense of shared space between the viewer and the photo. Instead of just watching, the viewer's presence now becomes part of the visual story. I believe this interaction can make the photo feel more alive, and encourage people to stay longer and look deeper.

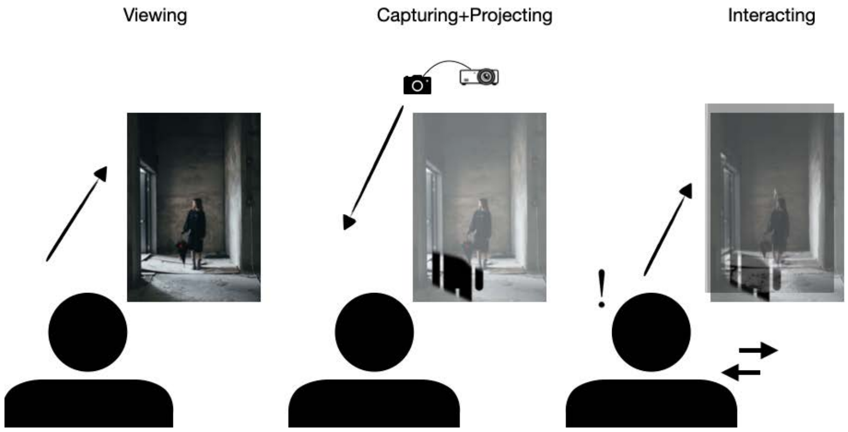


Figure 3.7 Design Space

3.3. Bouncy Photon Concept design

Based on the thought process described earlier, I began designing a working prototype centered around audience awareness and projection mapping using my own photo artworks. The core function of this system is to help regain the viewer's appreciation toward printed media particularly printed photography by introducing subtle, non-intrusive visual augmentation. The concept is simple: allow viewers to see themselves reflected in the printed photo they are observing, while keeping the original image intact and undisturbed.

The system, named BouncyPhoton, echoes this intention through its interaction flow. The first "bounce" occurs when the viewer encounters the photograph. The second bounce is triggered when a camera detects the viewer's presence. The third bounce involves the projection of visual feedback such as silhouette overlays or emphasized key features onto the print. The final bounce completes the loop when the viewer recognizes themselves within the altered visual frame, leading to a more intimate and reflective engagement with the photograph (See figure 3.7).

By softly embedding the viewer into the photographic space, BouncyPhoton invites longer and more thoughtful interaction, reigniting a tactile and emotional connection to printed imagery in a world increasingly dominated by digital screens.

Figure 3.8 Selected images from author's portfolio

3.3.1 Picking the Suitable Printed Photo

This system is designed to support printed photography using subtle, light-based augmentation. For the projection to work effectively, it is important to choose photographs that respond well to these enhancements. Since I have built a large collection of photographic artworks over the years at Rochester Institute of Technology, I decided to use my own works as the carrying medium for BouncyPhoton(See figure 3.8). Through testing, I found that some types of photos are more suitable than others. Images with rich lighting contrast, defined textures, or spatial depth tend to respond better to projection, while flat or minimalistic photos may not deliver the same perceptual impact.

Photos with clear lighting direction, mid-to-high contrast, and visible surface features such as highlights or shadows work best. These areas create opportunities for light-based projection to blend naturally into the image. For example, projecting a slightly brighter highlight onto an already-lit part of a face can enhance the photo's depth without changing its original tone.

Portraits and mid-range shots are especially effective because they usually have one or two focus areas, such as the eyes or face. This makes it easier to guide

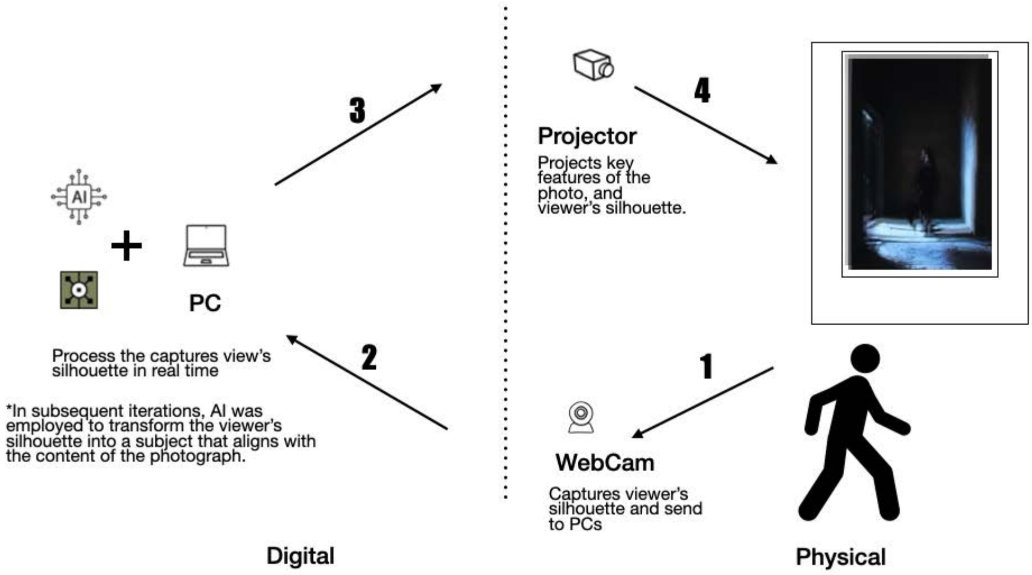


Figure 3.9 System Architecture

attention using subtle projection. In contrast, wide landscapes or images with very flat lighting are more difficult to augment because there is less structure for the light to interact with.

All test photos were printed on matte paper to reduce surface reflections. This helps the projection stay integrated with the photo, rather than appearing as a separate or floating layer. Through manual selection and observation, I chose photos that made the projection feel like part of the original image rather than something added on top.

3.3.2 Hardware Setup

The system uses a combination of a projector, a computer and a camera(it can be substituted by a depth sensor such as Kinect) to create a synchronized projection environment for printed photographs. Each hardware component plays a specific role in the projection and interaction pipeline(See figure 3.9).

The projector is used to display the light-based enhancements directly onto the printed photo. Its brightness and resolution are adjusted to match the viewing environment and photo size. The webcam is placed near the projector and used to detect the position and orientation of the printed photo in real time. This allows the projection to stay aligned with the image, even if there are slight shifts in camera angle or surface placement.

The camera is installed facing the viewer to capture their position and silhouette. This silhouette is processed and used as a dynamic mask that controls where the projection appears or disappears. As the viewer moves, their shadow or presence interacts with the projected content, creating a more responsive and immersive experience.

The computer serves as the central processing unit for the entire system, running TouchDesigner to handle both input from the camera and output to the projector. While AI was not employed during the exhibition to maintain consistency across viewer experiences, later iterations incorporated AI to transform the viewer's silhouette into forms that contextually align with the content of each photograph.

All hardware components are fixed onto a frame or mount to keep the alignment stable. A personal computer is used for data processing, projection control, and rendering, with all visual logic managed in TouchDesigner. The physical setup is designed to be compact and easy to install in gallery or exhibition spaces(See figure 3.9).

3.3.3 Software Pipeline

The image processing part of this system is built using TouchDesigner, a node-based visual programming environment that allows for real-time image processing, tracking, and projection control. The software pipeline is divided into three main parts: photo detection, feature processing, and audience interaction.

First, before the exhibition begins, I import the pre-stored reference image into TouchDesigner's Moviefile In node. Each image is then carefully processed through a customized pipeline using nodes such as Blur, Threshold, Edge, Monochrome, and Cache. The structure of the processing pipeline varies depending on the content of each photo, for example, darktoned, lighttoned, or high-contrast scenes require different treatment.

Next, the same image is sent through a secondary processing pipeline designed to extract its key visual features. These may include highlights, textures, edge contrasts, and internal lighting information. The extracted features are composited using a Composite TOP, where they are overlaid onto the original image to verify that the key elements are effectively emphasized without disrupting the original composition.

Once the processing is complete, the enhanced key features are projected back onto the printed photograph. To ensure accurate spatial alignment between the digital and physical media, a Mapping node called STONER is used to calibrate the projection, aligning it precisely with the printed counterpart.

At the same time, the web camera captures the viewer's silhouette in real time. This silhouette is turned into a live mask that can block or reveal certain parts of the projection. For example, when a viewer stands in front of the photo, their shadow may cause certain projection effects to disappear or shift position. This makes the viewing experience more interactive and immersive.

All inputs and outputs are processed in real time using TouchDesigner's built-in operators. The final result is a layered projection that responds to both the photo's structure and the viewer's body. This setup allows the printed photo to remain untouched, while the projection adds a quiet layer of interaction and emphasis.

Chapter 4
Proof of Concept

Here, we experimentally illustrate the potential application through implemented demonstration, as aligned with the potential applications illustrated in figure.

4.1. Photography Exhibition with BouncyPhoton System in BnA

To demonstrate that the prototype supports the original hypothesis, the most direct approach was to observe how a group of unbiased viewers interacted with printed photographs enhanced by the BouncyPhoton system. Fortunately, I was able to use my own photographic works as the content for this experiment.

My hypothesis is simple: if the BouncyPhoton system works as I intended, then three things should happen. First, viewers will spend more time in front of the photographs compared to standard printed works. They will feel curious and engaged, and they will start asking questions about what they're seeing. Second, they will notice and be drawn to the key visual features that the system highlights such as areas of texture, brightness, or contrast and they will lean in to examine them more closely. Finally, they will begin to move their bodies side to side to interact with the projected visuals, noticing how their movement changes what is shown on the prints.

If these reactions are observed, then my assumption that BouncyPhoton can increase attention toward printed photography, can be considered validated through this proof of concept.

4.2. Exhibition setup

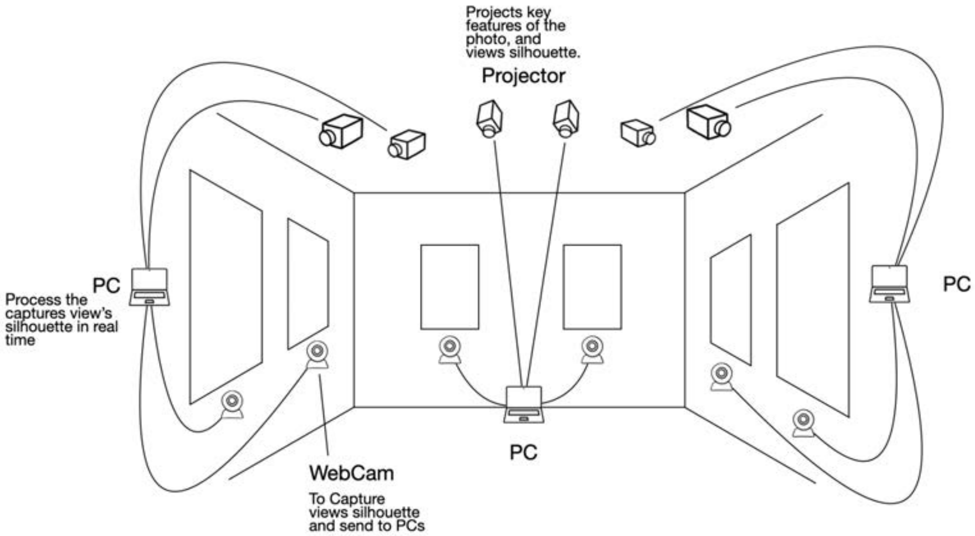


Figure 4.1 The full setup diagram of the exhibition room

The first public exhibition of this system was held at BnA(Bed and Art) Hotel in Nihonbashi, Tokyo, in a gallery-style environment that included printed photographs, five projectors, and five webcams(one extra setup for backup) (See figure4.1, 4.2). The goal of the exhibition was to present the BouncyPhoton concept in a real-world setting and observe how general audiences interacted with the augmented photos.

One photo was printed on matte paper and mounted on a flat wall. Above it, a projector was installed to project enhancements such as tone shifts and highlights. A webcam was used to track the alignment of the photo, while a web camera positioned in front of the space captured the silhouettes and movements of viewers(See figure 4.3).

The lighting conditions in the room were dimmed to allow the projection to remain visible without overwhelming the photo. The setup was designed to run continuously and automatically, without user instruction, to simulate a natural

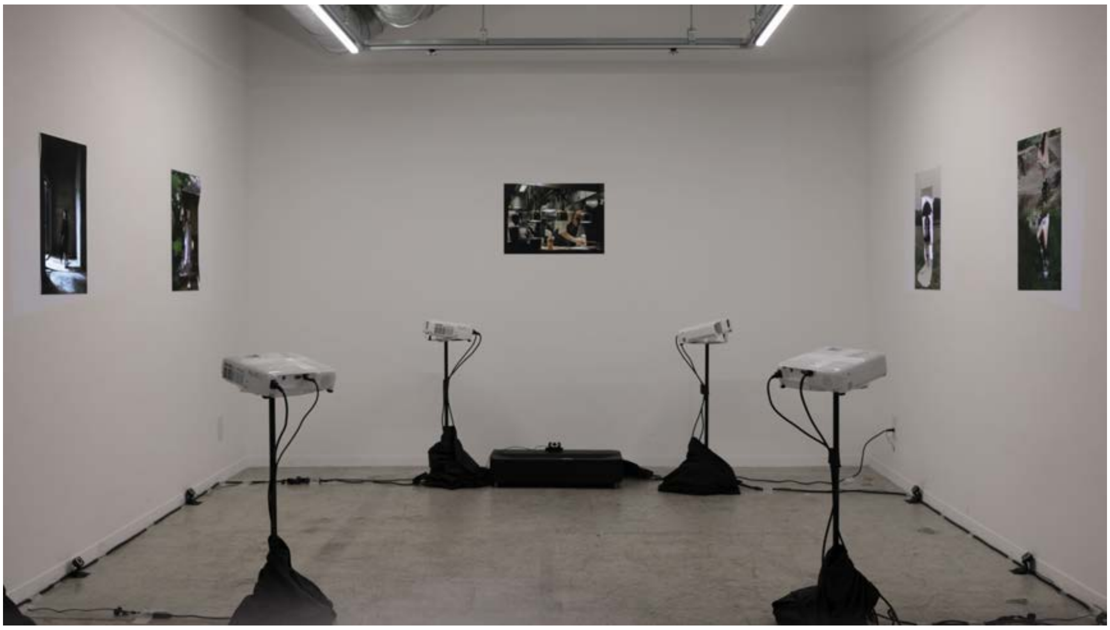


Figure 4.2 The full setup of the exhibition room

gallery experience.

4.2.1 Data Obtained from Exhibition

Before the exhibition, we also prepared a set of questionnaires for the audience to complete after their visit. The questions were divided into three categories: the first focused on the participant's background knowledge and familiarity with photography; the second addressed specific impressions of the photographs shown in the exhibition; and the third explored the emotional and reflective responses viewers had after experiencing the installation.

First type of questions.

> "How regularly do you visit photography exhibitions."
> "Do you have experience with printing physical copy of photography."
> "How do you take photos?"
> "In what method do you usually view your photos?"

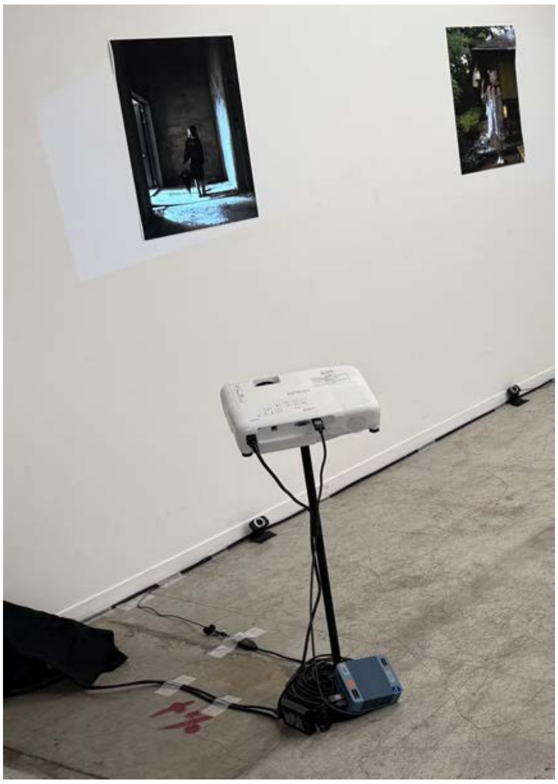


Figure 4.3 One BouncyPhoton System

Second type of questions.

In what way does the projection helped you to view this specific photo?
In short: How do you like this specific photo? (Or not

Third type of questions.

Rate from 1 to 7, how much do you felt connected to the story behind the photo.
Rate from 1 to 7, How much does the photo influence you as an audience.
Rate from 1 to 7, How much do you think you influenced the photo visually.
Rate from 1 to 7, The projection helped guide my attention to specific parts of the photo.

> In which part do you think this exhibition is superior to the traditional photo viewing exhibition?

During the exhibition, visitor behavior was observed informally. I recorded video footage from a side camera and took notes on audience reactions, body movement, and how long people spent in front of the photo. Some visitors interacted actively—stepping into the projection zone and watching their silhouette change the appearance of the photo. Others stood back and observed from a distance.

In general, visitors stayed longer in front of the augmented photo compared to nearby non-projected images in the same room. Some people noticed how the light changed on the surface and commented on the “glow” or the “feeling of presence.” One guest mentioned it felt like the photo was “breathing,” while another said it felt like they were “part of the photo.”

Although no formal questionnaire was used, these casual reactions provided early feedback on how implicit projection could increase engagement.

4.2.2 Evaluation and Analysis

First, I will analyze the exhibition using the collected data. The show attracted nearly 30 visitors in total. Out of these, 23 visitors provided their names and completed the questionnaire. Let’s begin by reviewing the responses to the first type of questions, which focused on the background of the visitors.

Among the 23 participants, more than half had experience printing photographs. For the second question, 50 percent said they typically use their smartphones to take pictures, while 14ngpercent reported using film cameras(a response that made me particularly happy). In the third question, half of the visitors responded that they view their old photos via social media apps on their phones. Not a single participant mentioned using printed photographs to revisit their memories(See figure 4.4).

From these responses, we can conclude that although many visitors have printed photos in the past, the majority now rely on smart devices both to capture and review their images. This insight supports my earlier observations regarding contemporary photographic habits.

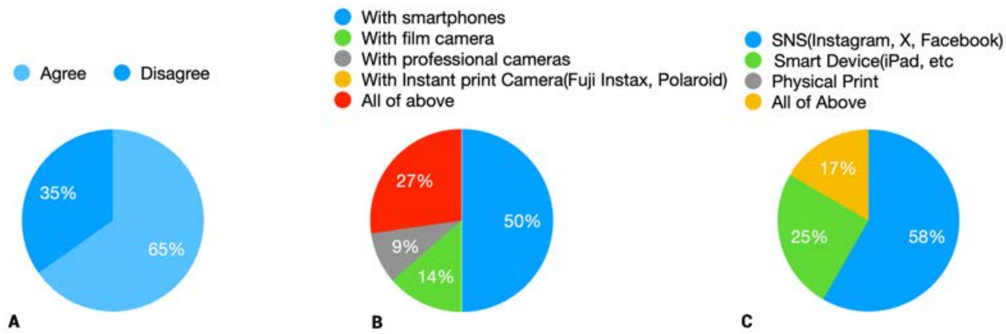


Figure 4.4
A:Do you have experience with printing physical copy of photography.
B:How do you take photos?
C:In what method do you usually view your photos?

Next, let's examine the second type of questions, specifically referring to the photo of the girl with an umbrella standing by the door(See figure 4.5). One visitor wrote:

> "Probably my favorite. It felt like I was a part of the picture my shadow moving within the frames of the light. It captivated me the for the longest amount of time compared to the other photos."

Another shared:

> "Gave a stronger impression that the audience influences art by changing shadow and field of view."

And another said:

> "I feel the photo is more dramatic from the amplified sense of light coming through the door contrast with the shadows I cast by moving in front."

From these three responses, we can see that the audience found the silhouette projection both intriguing and engaging. The phrase "captivated me for the

Figure 4.5 “Untitled”

Figure 4.6 “Chef”

longest amount of time” directly supports the hypothesis I presented at the beginning of the proof of concept: that the BouncyPhoton system encourages longer engagement with printed photography. In this sense, I consider the concept a success.

Now, let’s look at the third type of questions. One of them asked:

> “Rate from 1 to 7, how much did you feel connected to the story behind the photo?”

Of the 23 respondents, 12 gave a score of 5 out of 7, 6 gave a 6, and 4 gave the highest score of 7(See figure 4.7). Although this distribution centers around the average, conversations I had with some of the participants revealed that emotional responses varied depending on the photo. Some felt nostalgic, while others described a sense of eeriness. Overall, we can say that viewers did feel a degree of emotional connection with the printed photographs.

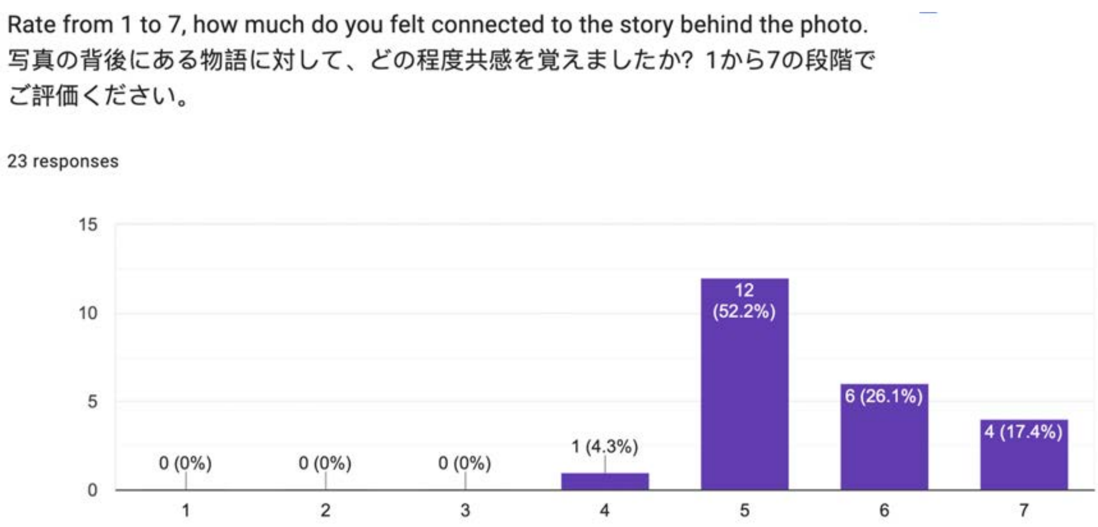


Figure 4.7 Rate from 1 to 7, how much did you feel connected to the story behind the photo?

In addition to this data, I also recorded audience reactions with my action camera. Reviewing the footage, I observed that even without explicit instructions, the subtle projection effects were able to draw and hold people's attention. In particular, when viewers noticed their silhouettes becoming part of the photos, they showed clear signs of curiosity and engagement. This suggests that even in the absence of touchscreen interfaces or guided interaction, bodily engagement alone can strengthen emotional bonds with static imagery.

Furthermore, I received direct feedback during conversations with visitors. One participant shared that when viewing the photo of the chef preparing food(See figure 4.6), the flickering of light which triggered by her movement toward or away from the image created a horror-like atmosphere. She mentioned that the bluish color tone and the flickering projection reminded her of a horror video game. Interestingly, she said that the image did not feel eerie at all when the projection was blocked by hand, further emphasizing the psychological influence of the projection(See figure 4.8 right and 4.9).

Despite some limitations, the feedback and behavior of the visitors confirmed that the system functioned as intended. It encouraged people to pause, observe

Figure 4.8 Left: Audience reacting to the system Right: Conversation with Audiences

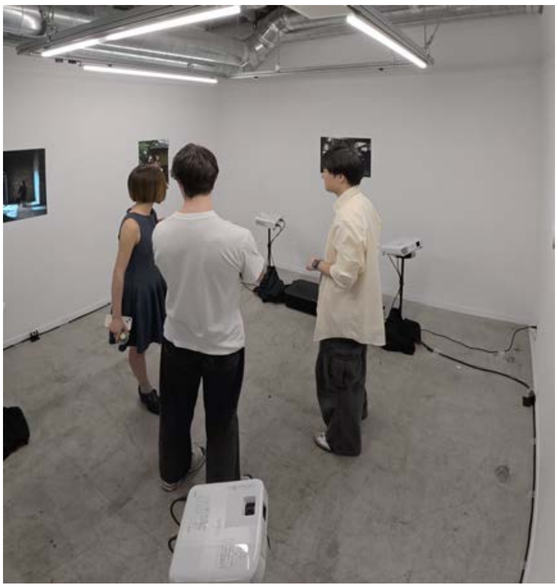


Figure 4.9 Audience having conversation with the author

more deeply, and immerse themselves in the photographic moment. These findings support the core objective of this research: to use non-destructive, audience-responsive projection to give printed photography a renewed sense of presence and interactivity.

Chapter 5
Discussion

Throughout the development of BouncyPhoton, we encountered several challenges, both technical and creative related to hardware constraints, material properties, and image content. While we aimed to build a flexible and broadly applicable system, certain limitations remain, and not all goals were achievable under current conditions.

5.1. My Belief in Printed Photography and Its Future

First, I believe printed photography can still remain relevant, even in an age dominated by digital media. Since the COVID-19 pandemic ended more than two years ago, people have returned to their daily routines, and many are placing greater value on their physical lives than ever before. From my observations, face-to-face interactions are increasing, and people are showing renewed interest in the tangible objects that surround them. This shift suggests that viewers may no longer be satisfied with just images on screens or even traditional prints on their walls, there is space for something more.

I believe that enhanced printed photography augmented through interactive systems like BouncyPhoton has the potential to engage people in new and meaningful ways. During my exhibition at BnA Hotel, I saw visitors interacting playfully with the system. Many approached me with thoughtful questions, some artistic, some technical, and it indicating a genuine curiosity about the work. This reminded me of an earlier project I created in 2017 at RIT called FlipGIF, where I projected animations onto printed photos. At that time, one of the visitors even asked to purchase the prototype on the spot. I declined, as I still had two more days of exhibition, but in hindsight, that moment felt like an early signal of the concept's potential.

With media technologies becoming increasingly sophisticated, visual content continues to grow denser and more "futuristic." Yet I believe that still photography will always have a place in people's hearts. A single photograph freezes time in one frame, and the space beyond that frame is filled by the viewer's imagination. Just as literature persists throughout human history, because our minds naturally fill the gaps between words, photographs allow viewers to fill the silence between frames. The BouncyPhoton system does not attempt to turn still images into video. Instead, it supports the audience's experience, gently guiding attention and enriching perception. It acts not as a replacement, but as an assistant just like a footnote in books helping viewers connect more deeply with the printed image.

5.1.1 Limitation of BouncyPhoton Concept

One of the major challenges in this research and exhibition came from the physical limitations of projection equipment. Fundamentally, light travels in straight lines and is blocked by opaque objects in its path. Based on this simple but essential physical principle, my experiments were often constrained by the spatial layout of the exhibition venue. However, this also led me to wonder: What if the light were intentionally blocked? And what if the material used to block it were semi-transparent? Such an approach could create a different viewing experience, offering new layers of interaction. This might be a promising direction for future iterations of the project.

Light intensity was another critical factor. When the ambient lighting was too strong, the projected visuals lost subtlety, and the printed photographs themselves suffered in color accuracy, appearing washed out. On the other hand, in overly dark environments even when I tried to reduce the brightness but most commercial high-definition projectors still emit a minimum of around 800 nits, which can be quite overpowering in dim settings. This made the projection too dominant, taking attention away from the printed photograph, which was intended to be the main subject.

As a result, balancing ambient light and projection intensity became an interesting and important challenge in this exhibition. It reminded me of an essential lighting principle I learned during my time at RIT: the inverse square law [36]. That principle turned out to be especially useful and applicable in this context.

5.1.2 Contents-Dependency

In this research, I feel truly honored and fortunate to have been able to use my own photographic works as the projection surface. Naturally, the content of the photos became one of the main factors influencing the BnA exhibition. The content of the printed photograph plays a crucial role in how effective the system can be. For example, since many of my works are portrait-based, it made sense that most of the pieces shown in this exhibition would be portraits as well. However, if you look at the five selected works from my photography/reference set, you'll notice that they are all environmental portraits and in four of the five, the faces of the subjects are not clearly visible.

This was intentional. I felt that having too many visible human faces could affect the way viewers prioritize their gaze. People naturally tend to look at faces first, which might interfere with how BouncyPhoton directs their attention. Beyond just the human subjects, the tonal structure of the photographs, the balance between light and dark areas, the placement of highlights and shadows—also affects how people observe images and could influence the system's performance.

Although this proof of concept confirmed my hypothesis, if I had another chance in the future, I would probably use a more consistent set of images. If possible, I'd even set up two identical exhibition rooms one with the system and one as a control to better measure the effect. This exhibition also reignited my passion for creating environmental portraits. Moving forward, I might consciously incorporate or adjust photographic key features that the BouncyPhoton system can work with, so that my future artworks are inherently compatible with projection-based interaction. Maybe this will even become the main inspiration for my next creative direction.

5.2. Future works

To all future researchers or photographers (or as I'd like to call them, visual engineers) who may come across this thesis. If anyone continues to feel passionate about printed photography, I hope you will explore ways to elevate its presence in spatial storytelling, especially by leveraging future advancements in hardware technology. I also encourage you to actively incorporate the BouncyPhoton system into your creative practice. It has the potential to bring a stronger sense of presence and immersion to your photographic works.

At the same time, I believe that with the rapid development of AI technologies, BouncyPhoton can benefit greatly from modern image recognition capabilities. One of my future visions is to achieve full automation of the system. In this ideal version, BouncyPhoton would be able to detect the content of a printed photograph on its own, automatically identify the key features worth enhancing, and even calibrate the projection angle without any manual setup.

Chapter 6
Conclusion

In this research, I explored the significance of printed photography in human society. Printed photos carry family memories, document historical moments, and act as a visual medium of communication. However, based on my observations from photography exhibitions over the past two years, people seem to be losing patience with printed photographs. Visitors spend less time in front of each image, favoring bold, trendy content instead. Academic research and literature also suggest that the rise of handheld digital devices has further drawn attention away from physical prints.

When I became aware of this shift, I decided to revisit a media art project I developed during my time at RIT, titled FlipGIF. It was an experimental installation consisting of a stack of printed photos, a pressure switch, a tripod, and a small projector. The photos depicted a stop-motion sequence of me walking from a parking lot to my exhibition booth. I used the physical mass of the photo stack to trigger the projection—when the audience placed the stack on the pressure switch, it activated a software that projected the corresponding animation directly onto the photos. This project combined interactivity with artistic expression and laid the groundwork for what would later become BouncyPhoton.

BouncyPhoton evolved beyond the original concept. Instead of using weight as a trigger, it employs a webcam to detect the viewer's presence from a distance. It projects audience silhouettes onto printed photographs displayed on the wall. Using a larger projector and high-resolution prints, along with more complex image processing techniques, the system now generates key feature maps—highlighting edges, contrasts, and lighting structures within each photo. As viewers approach the work, their motion and presence are captured and transformed into silhouettes or ripples, subtly layered onto the photographs. These projections are intentionally understated. If viewers do not pay close attention, they might not even notice the augmentations at first. My goal with this prototype was to test whether adding subtle, interactive projection to printed photography could increase viewer engagement and lengthen the time they spend appreciating the work.

I was fortunate to receive support from BnA WALL Hotel, where I held an exhibition titled Bound by Light. This was not a typical photography exhibition. Each work was enhanced using the BouncyPhoton system, incorporating quiet, layered projections onto the printed photos. From audience reactions, I noticed they became curious about the projected highlights and key features. Conversations with visitors revealed their openness to this hybrid format. I also distributed questionnaires to gather more structured feedback. The responses confirmed that the system helped some viewers connect more deeply with the artwork and extended their time spent in front of the images.

After the exhibition, I discussed the future of BouncyPhoton with my professor, peers, and attendees. Although this project currently focuses on printed photography due to its personal significance to me, many saw the potential for its application in other physical media, such as oil paintings or graffiti. I also reflected on the system's limitations. For instance, the webcam sometimes struggles to detect silhouettes accurately when visitors wear certain colors, resulting in a faint projection. I hope to improve these shortcomings with more advanced sensing equipment in the future.

This concludes my research journey. I'm deeply grateful to Keio Media Design for providing me with full support and the opportunity to pursue my dream of reviewing, restoring, and reactivating the experience of printed photography. I sincerely hope this work will inspire renewed attention to the value of printed images in our increasingly digital world.

References

[1] Rebecca Jeffrey Easby. Smarthistory - louis daguerre, *boulevard du temple*, paris, 2015. Accessed: June 12, 2025. URL: https://smarthistory.org/daguerre-paris-boulevard/.

[2] Julien Anido and Julien Anido. The first picture of a human being taken in Paris in 1838 — Un jour de plus à Paris, 7 2020. Accessed: September 14, 2025. URL: https://unjourdeplusaparis.com/en/paris-insolite/premiere-photo-etre-humain-paris-en-1838.

[3] Harry Ransom Center. Niépce heliograph. https://www.hrc.utexas.edu/niepce-heliograph/, n.d. Accessed: 2025-06-17.

[4] Naomi Rosenblum. *A World History of Photography.* Abbeville Press, 3rd edition, 1997.

[5] Nancy A Van House. Personal photography, digital technologies and the uses of the visual. *Visual studies*, 26(2):125–134, 2011.

[6] Mette Sandbye. Looking at the family photo album: A resumed theoretical discussion of why and how. *Journal of Aesthetics & Culture*, 6(1), 2014. URL: https://doi.org/10.3402/jac.v6.25419.

[7] Susan Sontag. *On Photography.* Farrar, Straus and Giroux, 1977.

[8] Alma Davenport. The history of photography: an overview. 1999.

[9] Geoffrey Batchen. *Each Wild Idea: Writing Photography History.* MIT Press, Cambridge, MA, 2001.

[10] Annette Kuhn. Photography and cultural memory: A methodological exploration. *Visual Studies*, 22(3):283–292, 2007. URL: https://doi.org/10.1080/14725860701657175.

[11] Kamal A. Munir and Nelson Phillips. The birth of the 'kodak moment': Institutional entrepreneurship and the adoption of new technologies. *Organization Studies*, 26(11):1665–1687, 2005. doi:10.1177/0170840605056395.

[12] Henry C Lucas Jr and Jie Mein Goh. Disruptive technology: How kodak missed the digital photography revolution. *The Journal of Strategic Information Systems*, 18(1):46–55, 2009.

[13] Roland Barthes. *Camera Lucida: Reflections on Photography.* Hill and Wang, 1981. Originally published in French as "La Chambre claire".

[14] Marshall McLuhan. *Medium is the Message: An Inventory of Effects.* Hardwired, 1996.

[15] Marshall McLuhan. *Understanding Media: The Extensions of Man.* McGraw-Hill, United States of America, 1964.

[16] Jianli Liu, Edwin Lughofer, and Xianyi Zeng. Aesthetic perception of visual textures: a holistic exploration using texture analysis, psychological experiment, and perception modeling. *Frontiers in computational neuroscience*, 9:134, 2015.

[17] Ramin Farnood. Optical properties of paper: theory and practice. In *Advances in Pulp and Paper Research, Oxford 2009, Transactions of the XIVth Fundamental Research Symposium*, pages 273–352. FRC, Manchester, 2009. doi:10.15376/frc.2009.1.273.

[18] Kevin Moore and Marion Perceval, editors. *The Proof of Color: Photographs by Jacques–Henri Lartigue.* Atelier EXB Editions, Paris, 2024. Includes contextual commentary highlighting Lartigue's generosity in sharing prints.

[19] Hiroshi Ishii, Amanda Parkes, Scott Brave, Brygg Ullmer, Ben Recht, and Jeevan Kalanithi. I/O Brush: Drawing with everyday objects as ink. In *SIGGRAPH 2004 Emerging Technologies.* ACM, 2004.

[20] Ivan Poupyrev, Jonas F. Taylor, Gilles Blasko, and Alex Sethuram. Display-objects: Prototyping functional physical interfaces on 3d styrofoam, paper

or cardboard models. In *Proceedings of the 4th International Conference on Ubiquitous Computing (UbiComp)*, pages 241–246, Göteborg, Sweden, 2002. Springer.

[21] teamLab. teamlab official website, 2025. Accessed: 2025-01-22. URL: `https://www.teamlab.art`.

[22] Amit H. Bermano, Olga Sorkine-Hornung, Bernd Bickel, and Wolfgang Heidrich. Deformation lamps: Revisiting the deformation illusion in static images. *Computer Graphics Forum*, 31(2):55–64, 2012. `doi:10.1111/j.1467-8659.2012.03028.x`.

[23] Brett R. Jones, Hrvoje Benko, Eyal Ofek, and Andrew D. Wilson. Illumiroom: peripheral projected illusions for interactive experiences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, page 869–878. Association for Computing Machinery, 2013. URL: `https://doi.org/10.1145/2470654.2466112`.

[24] Rajinder Sodhi, Hrvoje Benko, and Andrew Wilson. Lightguide: projected visualizations for hand movement guidance. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, page 179–188. Association for Computing Machinery, 2012. URL: `https://doi.org/10.1145/2207676.2207702`.

[25] Volkswagen. Projection mapping on a book. YouTube video by Geckow Smarte Mediensysteme, 2015. Accessed: 2025-06-19. URL: `https://www.youtube.com/watch?v=xqnFSAUnDww`.

[26] Takashi Nomoto, Wanlong Li, Hao-Lun Peng, and Yoshihiro Watanabe. Dynamic multi-projection mapping based on parallel intensity control. *IEEE Transactions on Visualization and Computer Graphics*, 28(5):2125–2134, 2022.

[27] David C. Lindberg. *Theories of Vision from Al-Kindi to Kepler*. University of Chicago Press, Chicago, 1976.

[28] Daniel J Simons and Daniel T Levin. Change blindness. *Trends in Cognitive Sciences*, 1(7):261–267, 1997. `doi:10.1016/S1364-6613(97)01080-2`.

[29] Daniel J. Simons and Christopher F. Chabris. Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Psychological Science*, 10(2):105–110, 1999. doi:10.1111/1467-9280.00142.

[30] Frank Steinicke, Gerd Bruder, Klaus Hinrichs, and Pete Willemsen. Change blindness phenomena for stereoscopic projection systems. In *2010 IEEE Virtual Reality Conference (VR)*, pages 187–194, 2010. doi:10.1109/VR.2010.5444790.

[31] Daniel J. Simons and Christopher F. Chabris. Selective attention test. https://youtu.be/vJG698U2Mvo, 2010. Accessed: 2025-06-17.

[32] Kira Zhong. Flipgif (interactive projection installation). Vimeo video, 2017. Accessed: 2025-06-19. URL: https://vimeo.com/217784385.

[33] Paolo Sacchi. *Lo sguardo rallentato: Esperienza estetica e fotografia tra attention economy e immagini tecniche*. PhD thesis, Università di Parma, 2023. PhD Thesis. URL: https://tesidottorato.depositolegale.it/handle/20.500.14242/178471.

[34] L. Glass and M. A. Smith. Glass patterns. *Scholarpedia*, 6(8):9594, 2011. revision #137324. doi:10.4249/scholarpedia.9594.

[35] Kanghong Zhong, Kiryu Tsujita, Takatoshi Yoshida, and Kouta Minamizawa. A study on overlaying modified images onto unmodified prints towards implicit visual guidance. In *Proceedings of the 29th Annual Conference of the Virtual Reality Society of Japan (VRSJ 2024)*, pages 1–4, 2024. Paper 2E2-10. URL: https://conference.vrsj.org/ac2024/program/doc/2E2-10.pdf.

[36] Nikolaos Voudoukis and Sarantos Oikonomidis. Inverse square law for light and radiation: A unifying educational approach. *European Journal of Engineering and Technology Research*, 2(11):23–27, 2017.

Appendices

A. Questionnaires

This section presents all questionnaires used in the survey. As mentioned in Section 4 (see Figure 4.4), three types of questionnaires were employed during the exhibition.


How regularly do you visit photography exhibitions.
写真展にはどのくらいの頻度で訪れますか。

- Once a week（週に一度
- Once a month（月に一度
- Once a few month（数ヶ月に一度
- Once a half year（半年に一度
- Once a year（年に一度
- Never in past year（過去1年間に一度もなかった

Do you have experience with printing physical copy of photography.
写真のプリントした経験はありますか。

- Disagree（反対
- Agree（同意

How do you take photos?
普段はどうやって写真を撮るんですか?

- With Smartphones（スマートフォン
- With Film Cameras（フィルムカメラの場合
- With Professional Cameras（プロカメラ、ミラリス、一眼
- With Instant print Cameras (e.g. Fuji Instax, Polaroid
- All of above

In what method do you usually view your photos?
普段はどのような方法で写真を閲覧していますか?

- SNS(Instagram, X, Facebook...)
- Smart Device(iPad,)
- Physical Print
- All of Above

Figure A.1 First set of questionnaires

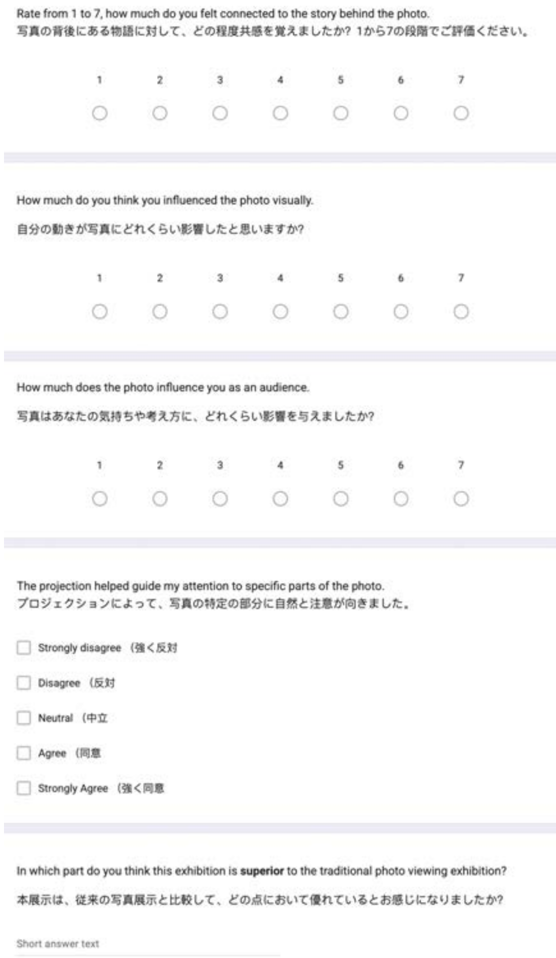
From here, we gonna ask your experience of BouncyPhoton Exhibition.

Description (optional)

In what way does the projection helped you to view this specific photo? In short: How do you like this specific photo? (Or not

この写真の鑑賞において、プロジェクションはどのような影響を与えましたか? （または、与えなかったですか? ）

Figure A.2 Second set of questionnaires



Rate from 1 to 7, how much do you felt connected to the story behind the photo.
写真の背後にある物語に対して、どの程度共感を覚えましたか? 1から7の段階でご評価ください。

1 2 3 4 5 6 7

How much do you think you influenced the photo visually.

自分の動きが写真にどれくらい影響したと思いますか?

1 2 3 4 5 6 7

How much does the photo influence you as an audience.

写真はあなたの気持ちや考え方に、どれくらい影響を与えましたか?

1 2 3 4 5 6 7

The projection helped guide my attention to specific parts of the photo.
プロジェクションによって、写真の特定の部分に自然と注意が向きました。

- Strongly disagree （強く反対
- Disagree （反対
- Neutral （中立
- Agree （同意
- Strongly Agree （強く同意

In which part do you think this exhibition is **superior** to the traditional photo viewing exhibition?

本展示は、従来の写真展示と比較して、どの点において優れているとお感じになりましたか?

Short answer text

Figure A.3 Third set of questionnaires

B. Updated Version of BouncyPhoton System

This section presents visual representations of the updated version of the BouncyPhoton system. These images were included in the submission to SIGGRAPH Asia 2025.

Figure B.1 A full setup with a viewer

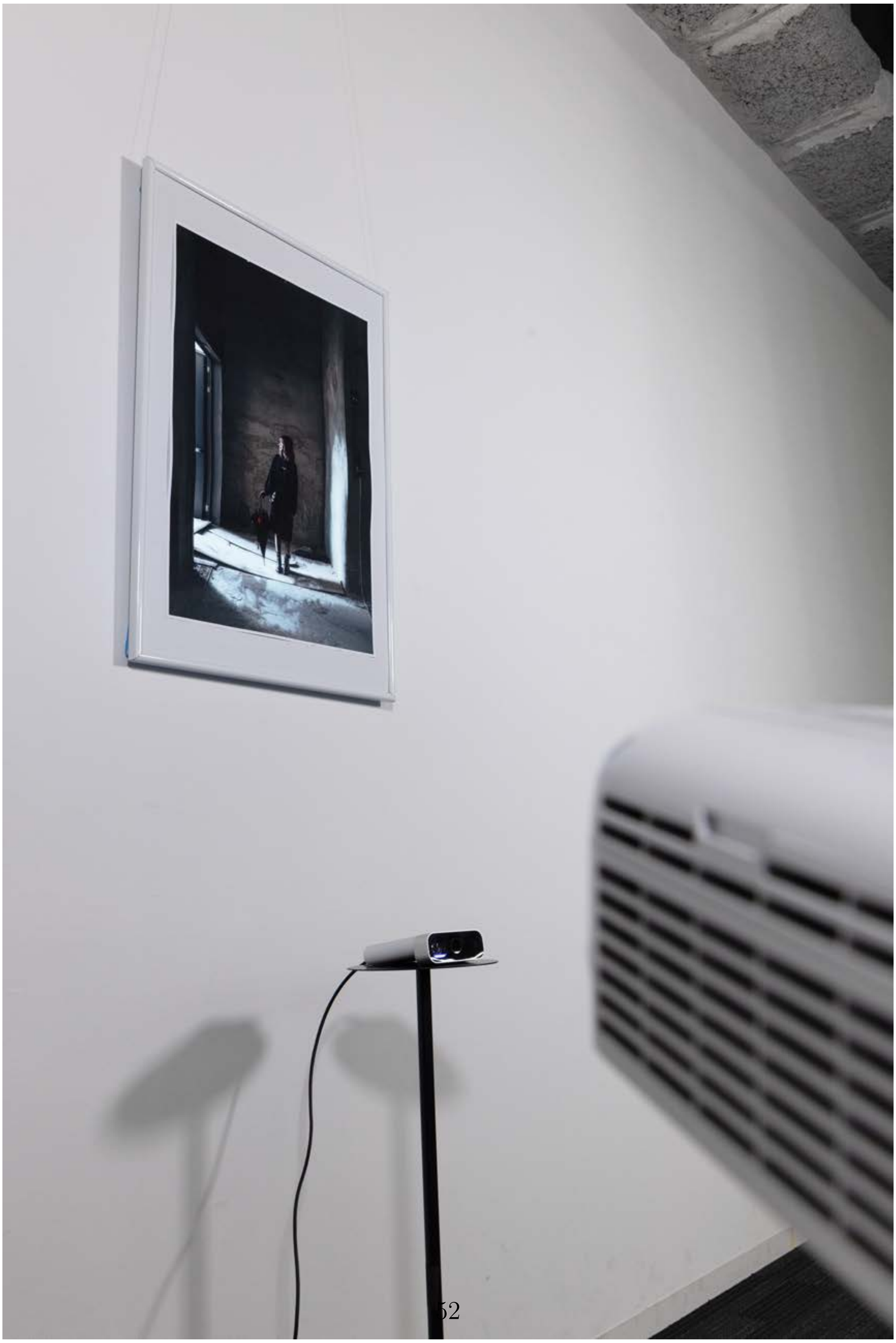


Figure B.2 Hardware setup

Figure B.3 Close up of the Photo