

# An Underdeveloped Metaphor: The Mismatched Designs and Motivations of Digital Picture Interactions

An Underdeveloped Metaphor

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Picture interactions are key to daily and long-term social connections between families and communities, especially through reminiscence. Across the nearly 200-year history of domestic photography, this social reminiscence has been accomplished largely through photo albums. However, in the now common digital setting, albums are pushed aside for the endless film roll metaphor. In this paper we explore this metaphor through the 20-year history of proposed digital picture interactions from Human-Computer Interaction research, and compare this to ongoing interactions with modern picture tools. Through these, we reveal that this prominent design metaphor does not create space for social reminiscence, but does fit the novel use of immediate sharing seen across social networking. Further, the endless and ever-growing nature of digital film rolls are not meaningfully browsable for either intended use. We close by reconnecting to the past works that explore the broad potential of digital pictures.

CCS CONCEPTS • Human-centered computing~Interaction design~Interaction design theory, concepts and paradigms • Human-centered computing~Collaborative and social computing~Collaborative and social computing theory, concepts and paradigms~Social content sharing

**Additional Keywords and Phrases:** Digital picture interactions, design critique, perspective-based inspection

## ACM Reference Format:

Benett Axtell, Eleen Gong, and Cosmin Munteanu. 2022. An Underdeveloped Metaphor: The Mismatched Designs and Motivations of Digital Picture Interactions. *ACM Trans. Comput.-Hum. Interact.* Just Accepted (October 2022). <https://doi.org/10.1145/3569887>

## 1 INTRODUCTION

Much of modern digital picture interactions build on the metaphor of a roll of film. This has been seen since the beginnings of digital picture tools in design elements such as timelines, slideshows, and camera rolls (see Figure 1). This metaphor is broad-reaching throughout both the history of HCI design research and modern tools, and therefore mediates how we access and interact with our photographs in digital spaces. Our photographs provide significant social connections to personal, family, and community settings [71], especially as a prompt for social reminiscence, which fosters a sense of self and maintains a connection to a larger past [14,69]. This general non-professional use of

photography, often called “domestic photography”, encompasses family and personal use of pictures along with more public use, such as community events [72]. Domestic photography is a key source of family narrative across generations, representing an easy and rich means to access our stories through the strong visual prompt of pictures. The social activities around pictures are broader than taking and viewing pictures, including intentional and unintentional organization, curation, storytelling, and much more [12,19].

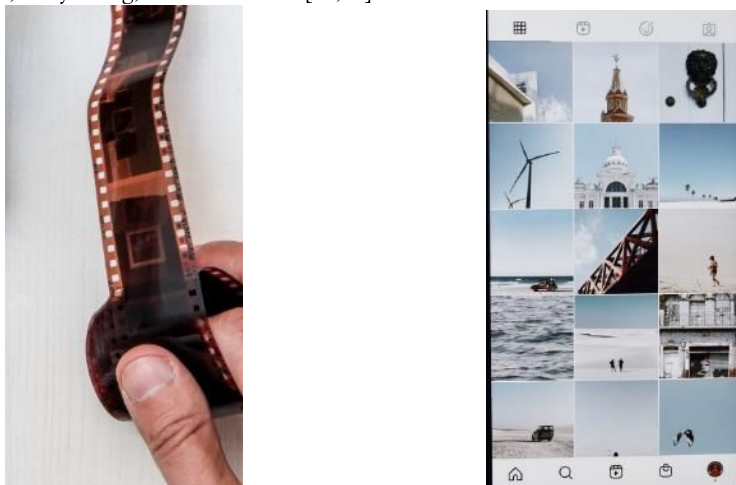


Figure 1. Left: A unrolled strip of exposed roll film (by NordWood Themes on Unsplash). Right: A standard digital picture view using a film roll metaphor (by Nathana Rebouças on Unsplash)

Interactions with digital pictures have been eclipsing those with analog pictures since the early 2000s, revolutionizing how we share and receive pictures [73]. However, digital designs still fail to consider the long-standing social interactions around pictures, namely reminiscence [12,89]. Social networking sites focus on novel picture interactions emerging from online settings, such as immediate social sharing (capturing a picture now to share now) over social reminiscence (capturing a picture now to share later) [74].

Numerous works have found that digital picture interactions fall short of user needs, especially around reminiscence and browsing e.g., [4,13,46,77,89]. The shortcomings of film roll interfaces has been observed in various aspects of digital picture interactions, including users being unable to identify where their own pictures are stored, leading to a feeling of distance [89] and viewing being “ruined” by the sole point of access being an endless chronological scroll through an entire collection [13]. Common picture interactions that use film roll metaphors, like photo galleries and slideshows, have been shown to be less effective at prompting memories and reminiscence than designs based in physical interactions [5]. We argue that these shortcomings are largely a result of the film roll metaphor, specifically as it removes a user’s control over viewing and browsing of their own content. We further argue that the prevalence of this metaphor over others in digital picture interactions stems from the adoption of default computer interactions that were common as digital pictures rose in use, namely file systems and the associated chronologically sorted scroll of files.

Digital spaces are often described as being divided into either database or narrative [54]. Though the range of picture activities (both physically and digitally) are broad and overlapping [12], digital picture interactions currently adhere to this divide with cloud storage tools as databases and social media networks as narrative [4]. This enforced divide of digital picture interactions further divides which picture activities can be done with which setting and therefore which activities can be connected. The need for cohesive digital picture tools that merge database and narrative uses was

recognized as early as 1999: early explorations of the possibilities for digital pictures highlighted the separation of digital “piles” and “files”, which roughly correspond to, respectively, narrative and database uses [67]. This has affected users’ mental models of picture tools and may have caused a shift in how we understand intended uses of picture tools, compared to physical settings [4].

Digital and physical picture settings also have little practical overlap. Unlike physical formats, like albums, the physical formats of common digital tools are not easily shared: multiple people cannot comfortably sit in front of a desktop (or laptop) computer and a smartphone screen is too small to practically share multiple pictures [6,29,77]. Further, a strong motivation to create physical prints of digital pictures is to access that social reminiscence, and a printed version of a physical picture is not seen as connected to the digital original [46]. All of this suggests how the prevalence of the film roll metaphor across digital picture interactions limits the story and narrative prompting qualities of pictures, which in turn limits reminiscence.

In this paper, we investigate the current and historical use of this design metaphor and through this demonstrate the broad significance of metaphor across digital spaces and the need for historical context in seemingly settled designs. We question the degree to which the film roll metaphor is applied. The reasoning behind the design of this metaphor has not been well explained, especially given its ubiquity. Given that the metaphor is out of place (the physical roll of film is not used for browsing or other home picture interactions) we see the film roll metaphor as underdeveloped: put in place without an understanding of the processes and tools it draws from as well as the needs of the processes it is nominally intended for.

To explore this, we investigate the potential origins of the metaphor and the evolution of its use to better understand its role in current use. Through this work, we show how careful targeted consideration of existing digital metaphors provides important insight into what is known and understood about current and past use. First, we review 20 years of proposed digital picture tools from past HCI works to identify how the film roll has been historically used, or not, across the research space. We then systematically review the presence of the film roll across popular social networking and cloud storage tools, through a perspective-based inspection using the model of PhotoUse proposed by Broekhuijsen et al [12], to reveal the extent of its modern, actual use. These two reviews of use in combination create a more complete presentation of picture interactions. The past research in this area is not seen reflected in available tools, and the designs of available tools do not make accessible their motivations or research background. As such, one approach is not sufficient to understand both the design motivations and actual possibilities of use that surround this pervasive metaphor.

From these two perspectives, one historical research and the other modern design, we find that a well-implemented film roll metaphor may have an important role to play in the novel immediate sharing use of social networking sites. However, we find that album-based metaphors would better support picture browsing tasks than a film roll can, and generally, the broad use of the film roll is a limitation to picture activities overall. We ground these findings in the range of designs proposed over the past two decades that have already explored album-inspired picture interactions. We propose to move browsing away from the needless overuse of this metaphor, which distances us from our pictures and the reminiscence that we keep pictures for.

## 2 THE FILM ROLL AS A DESIGN METAPHOR

Metaphors relying on analog or other more established technologies are commonplace in modern digital interactions and throughout the history of HCI, and much of modern digital interface design itself is built on the metaphor of the computer desktop. Other common metaphors include icons for saving, phone, and camera tasks all use out of date

technologies (floppy disk, handset, and camera, respectively). Clock and timer setting tasks often use analog clock faces as a quicker option to scrolling through a digital time display. Many of these metaphors are meaningful in digital spaces and have persisted for that reason.

Digital metaphors are powerful tools that ground users' interactions with novel settings, especially with familiar media such as ebooks, by building on the existing analog processes and understanding the digital setting. In this way, they can be leveraged to understand what initial tasks with a novel artifact could include. A turning page metaphor can work well for an ebook as it matches the same process of page turning in a physical book [92]. Another aspect of the physical book process, such as printing ink onto a page, would not be as intuitive or useful a metaphor. Just as printing a book is not the same metaphor as reading it, developing film is not the same metaphor as having and interacting with pictures.

Design artifacts, like digital metaphors, have a cyclical relationship with the tasks that can (or want to be) accomplished through that design. This task-artifact cycle describes how tasks lead to new requirements, resulting in new artifacts, and those new artifacts lead to new possibilities (or constraints), which lead to new tasks [17]. A novel design metaphor, as a starting point for an artifact, will evolve and refine within the task-artifact cycle as new requirements and tasks emerge.

Metaphors, linguistically, have been defined as "a device for seeing something in terms of something else. It brings out the thisness of that or the thatness of a this" [15]. In digital spaces, metaphor is often used to see the digital in an analog way, this can help to orient users, demonstrate a framework for use, and introduce novel designs [70]. The role of metaphor within HCI as well as the advantages and disadvantages of reliance on metaphor has been explored throughout the history of the field. Blackwell explores this history in depth, including the different levels and interpretations of metaphor as a design tool, and discusses a methodology for metaphorical design, emphasizing that when a metaphor describes one thing in terms of another it introduces a third piece: the relation between them [10].

More broadly the GUI, the nature of computing itself can be described as metaphorical, as in the work of Brahmam et al who explore the history of computing and the creation and development of the computer as an object to do women's work [11]. From their analysis, this origin contributes to the base metaphor of computer as a woman that continues to permeate much of technology design today and actively limits the potential of the computer because this perspective dictates the perceived possibilities of its use.

Saffer identifies metaphor as a design tool that can change user behaviour, such as the broader adoption of computers after the display metaphor shifted to that of a desktop [70]. McLuhan discusses metaphor from the Greek to "carry across"; something that bridges from one kind of experience to another [56]. He posits that new media enhances aspects of the old while rendering some aspects obsolete, but also retrieves aspects from before that old media and eventually reverses into the old. This evolving cycle of enhancing with new tasks and retrieving old also parallels the evolution of technology within the task-artifact cycle [17]. So, we must understand how the broad use of the film roll metaphor is affecting (enhancing, obsolescing, retrieving, reversing) people's interactions with their pictures in order to understand its usefulness.

The film roll metaphor is based in the tools and activities of modern domestic photography or what Sarvas and Frohlich call the "Kodak Path" (starting in the late 1880s to the 1990s) as Kodak cameras and Kodak film dominated the market, partially due to the innovation of the roll of film [75]. At that time, the roll of film was stored in a camera until all the pictures on the roll had been taken and then was brought to a store to be developed. The printed pictures were given to the user, generally in an envelope, who then used them as individual pages in various settings (e.g., albums, boxes, frames). Importantly, the film roll is not used, literally or metaphorically, after the development of pictures.

Pictures are not stored or displayed in a long, connected strip, or even using the strict chronology forced by the physical roll of film. Interactions with pictures are not served by that tool. A film roll is perhaps more like a USB drive that can be passed to a printer, but cannot on its own be used to access pictures. A study of the effective cues for memory retrieval from (physical) pictures identified that a strict external chronology is a weaker prompt for memory, partially because specific dates or times are not commonly stored as part of memory, and find that memories are prompted by some combination of the people, activity, and location in a picture [16]. Further, individual or loose pictures are stronger prompts for reminiscence, while endless scrolling of an entire collection limits or stops viewing [13,29,89]. Given these recognized weaknesses of linear time as a method of memory access, it is logical that we would move away from that strict chronology in our interactions with a primary medium for memory, namely physical pictures.

In a digital setting, however, a film roll's forced chronological order is seen across picture interactions, and has been since their invention. Camera rolls display pictures in the exact order they were taken, including near duplicates and unrelated pictures side by side. One-at-a-time slideshows use that same order, further removing the context between relevant pictures as it is unclear what will be shown next [13]. Social networking sites use an unknown algorithm to present content in the order they decide is best for a user, giving the user a similar experience to film roll viewing: the engineering has determined how the pictures can be viewed with no opportunity for user curation. Contrast these examples with standard physical picture interactions, such as small albums made by personal selection (often from a developed film roll) or framed pictures on walls.

The long history of domestic photography has seen several major shifts in technologies and in use, including the shift from analog to digital photography and storage. These shifts are well-researched, and are often included as examples in new media studies, perhaps because of the continued ubiquity of photography across these major shifts (e.g., [54]). We use the space of domestic photography to closely examine and question the use and impact of metaphor in the broader space of design and interaction. Our work demonstrates the importance of metaphor and specifically of the selection and design of metaphor within existing social systems of use.

We do not argue that a digital medium must exactly match the pre-existing physical one. Desired interactions can and do change over time as new tools and opportunities are presented. Photography has found many new uses with its new digital ease of access, including capturing now to share now. This immediate sharing is encouraged by the designs of these tools, as we discuss later in this paper. Yet the social reminiscence photography is clearly continuing now that digital pictures have been the norm for decades and despite the lack of digital access to those activities [4]. The Tools for Thought presented by Smyth et al warn against metaphors shifting from a way of thinking about a design into a solution for it and propose that designing with a metaphor should be informed by that metaphor, rather than led by it [80]. It seems that the current designs for digital pictures are being led by the film roll.

## 2.1 The Digital Film Roll Metaphor

The physical roll of film contains film negatives of a series of pictures taken in chronological order and physically attached to each other in that order. When developed, these are separated, and individual prints are returned to the photographer. In a digital setting, the film roll is seen in scrolling grid, timeline, and slideshow views that maintain that forced and un-editable order, which is generally chronological. Even when algorithms present a tool's optimized order instead of chronological order, the film roll is still present as the order is pre-determined by the technology rather than the user. These interfaces are often practically endless as new pictures are added multiple times a day, with no delineation within the collection. This endless scroll is not taken from the physical roll of film, which is, by necessity, finite, but may be an artifact of this finite limitation being essentially removed when moving into a digital space.

In the context of this metaphor, we define the following terms that embody it:

- **Forced Order:** Pictures are presented in an order that cannot be changed by a user in that a picture cannot be moved within the order, though pictures can often be added and removed through filtering, such as by facial recognition
- **Chronological Order:** Pictures are ordered by the creation timestamp. As a default order, such as in a digital album, this can often be manually changed by a user. In other cases, it is forced (see next definition)
- **Forced Chronological Order:** Pictures are ordered by creation timestamp and this order cannot be changed by a user.

### 3 FRAMEWORKS OF PICTURE USE

It has only been in the past few decades that domestic photography has been researched in sociological fields. These works create the basis for many of the models of digital use, as HCI researchers base their work in that of their analog predecessors. One of the key works understanding how we interact with (largely analog) pictures is that of Chalfen who looks at the physical picture uses of domestic photography and identifies demonstrating one's place in society as a key purpose of these pictures [18,19]. Looking at mothers' use of physical pictures, Rose finds that families engage in four key activities: dating and storing, displaying, looking at, and sending and printing [68]. Sandbye looks at three physical photo albums, each from a different culture, as examples of the variety of domestic use and confirms what previous works had found: that albums are used to "symbolically define and order the world", but also that not enough has been done to properly understand the variety of use and everyday practice [71]. Cushing explores the perceptions and characteristics of digital possessions, including pictures, through interviews with participants in times of life transition [24]. They find that digital possessions are those that have value and represent someone's identity, similar to the qualities of pictures often highlighted as supporting reminiscence. Keightley and Pickering investigate practices of digital photography as they relate to memory specifically and reveal shifts in four areas of picture interactions: photo-taking, photo-storing, photo-viewing, and photo-sharing [46]. Viewing many pictures on digital screens is not conducive to memory sharing, leading many of their participants to order printed photobooks. The benefit of digital viewing was seen in the randomness of a digital photo frame cycling through many pictures which seems to make the prompt stronger.

Rodden presents suggestions for digital picture interactions based in the organization of and use of physical personal picture collections in 1999, when picture interactions were still mainly physical [67]. Physical picture use is organized through a combination of "files" (e.g., albums) which are loosely chronological and "piles" (e.g., envelopes or boxes) which are largely unorganized, both of which Rodden finds should be brought into digital spaces for ease of access. Frohlich et al proposed requirements for digital photoware in 2002 based on real family picture use [29]. Their findings emphasize the importance of informal communication and sharing of stories across pictures. Work by Schiano et al from the same year focuses on teenage users, but finds many similarities to adult and general family use, especially that reminiscence is an important motivation for pictures [77]. Kirk et al build on Frohlich et al's work with their proposed model of photowork [48], which identifies three phases of work with digital pictures: pre-download, at-download, and pre-share. They also question the digital focus on directed search tasks over general browsing tasks as unrealistic. Further building on this, Broekhuijsen et al propose the PhotoUse model that identifies activities across four broad categories: accumulating, curating, retrieving, and appropriating [12], and find a need for these to be combined to support flexible variations in use. This work differs from the previous ones in that they do not identify a common path of picture activities, and instead present their model as a wheel of activities that can be done in any order, allowing for the broad variety in realistic use by different people. In particular, they identify that many of these activities are

combined towards a common goal of reminiscence, such as triaging a collection of pictures from an event and editing the selected ones into a format that can be shared for in person storytelling around that event.

Whittaker et al find that long-term retrieval is a major motivation of digital picture storage, but also that it is a particularly difficult task as the “out of sight” nature of digital settings makes access years later much harder [89]. Broekhuijsen et al redesign different picture use settings with participants to understand their needs for collaborative reminiscence from digital pictures, including user picture curation and access to a larger context of pictures [13]. Axtell and Munteanu look at the mental models of digital and physical picture tools across older and younger adult users and find that the two settings have distinct mental models, with little overlap [4]. These works highlight the lack of clarity and control for users of modern digital picture tools. Users do not control their access and interaction with their pictures within collections and so cannot curate their experiences. Many of these works reveal the same common organization structure of pictures: largely by event or other time signifier, but not strictly chronological unless forced by the computer [48,77,89].

#### 4 EXPLORATIONS OF DIGITAL PICTURE INTERACTIONS

Since 1999, HCI research has been proposing new tools to support casual picture interactions in digital spaces. These strive to meet the complicated, broad-reaching, and expanding needs of domestic photography with a large variety of settings and motivations. In this section, we present this history of digital picture interactions through our lens of how designs were created for those casual interactions (e.g., with a film roll metaphor). By examining the progression of design research over these two decades, we highlight potential motivations for the film roll’s current prevalence.

To present this historical perspective, we gather works that propose designs intended to encompass picture use, rather than those that focus on a specific subset of interactions (e.g., an algorithm to automatically cluster pictures by events, but without an interface to browse that picture collection). The works presented here highlight how designers and researchers have been exploring interactions with pictures throughout the history of digital photography and reveals the inconsistency of the film roll metaphor throughout that time, which we contrast to its prevalence in available tools in the next section. From the various designs and interactions with picture activities across this history, we propose that the film roll has been inherited from the pre-existing digital storage of file systems (another physical metaphor; from paper files stored in folders). This presented a path of least resistance to support pictures in digital spaces, as file storage was already established and built upon digital metadata commonly associated with pictures, like timestamps. By building off this established digital norm, the film roll metaphor quickly became the default digital picture interaction, and this ubiquity seems to have prevented alternative metaphors from gaining traction beyond the research space.

We present these tools in approximate chronological order based on date of publication, and divide this order into four subsections that reflect what we recognize as the trend of that section of time: starting with *early explorations* before digital pictures were the norm, followed by *rising use, new digital tools* as the new prevalence of digital pictures was explored through the established digital norms of the desktop computer as well as novel technologies like digital tabletops, then *common desktop use* where the majority of research has largely settled on familiar desktop computers as the source for digital picture interaction design, and finally *settled design standards* which includes the last decade of digital research and the decrease in design variety seen in this space. We summarize this section with a timeline showing all these works, along with other major milestones in digital picture tech use (presented in the previous section), at the end of this section in Figure 2.

#### 4.1 Early Explorations (1999-2002)

The earliest examples of research into digital picture interactions came before pictures were predominantly digital. These works explore the potential for bringing picture interactions into existing and novel digital spaces. The early digital picture interactions vary broadly in designs, building understandings of physical picture use (and early-adopter digital picture use) through observations and interviews. These largely used manual tagging, primarily of datetimes and people, and intend to bring picture browsing into digital spaces. FotoFile uses an album metaphor to create browsable space of photos in order to make digital multimedia more accessible to non-expert users [49]. The Zoomable Image Browser was created to bring the browsing of pictures into digital spaces and lets users zoom into higher resolution results based on a search term [23]. PhotoMesa (an iteration on [23]) and PhotoFinder both present pictures as groups, clustered by dimension or filtered by search term, respectively, and pictures within each group are ordered, perhaps by timestamp or relevance [9,45]. These continue to build on the earlier search and browse suggestions and try to keep browsing at the forefront of digital picture interactions.

Other early works tackle the issue of larger than ever picture collections created by new digital storage capacities by focusing on retrieval of pictures, as distinct from browsing, but still centred around some sort of browsing interface. MiAlbum uses semi-automatic tagging to reduce the effort and work of manual picture tagging and labeling in order to support broader search terms for retrieval [87]. With perhaps the earliest instance of an algorithmic order which is potentially hidden from users (as will become the norm much later on social networking sites), MiAlbum sorts picture results by relevance. Unlike the default chronological sort, this introduces new information to users, which might not be transparent or easily understood as the relevance-based sort on machine-applied tags create several steps of distance from the known metadata and content of a picture. The SmartAlbum supports picture searches by speech query using metadata from manual annotations [82]. The interface is a retrieval tool first, with most of the controls showing and supporting the different possible search modalities. The picture display is a grid listing of results and, while the query can include a date range, the interface does not include a timeline. These early explorations of retrieval were pushing the limits of the available technology to include speech and flexible query tools within picture applications. They included as much picture metadata as possible, combining picture metadata, manual tagging, and “smart” options to bring the novel capabilities of a digital space to picture browsing.

Though early works consistently use time as a data dimension and may have some time-driven aspect of the interaction, none of these use a film roll metaphor as the core interaction of retrieving activities with pictures. Many of these use aspects of available file systems, such as folder hierarchies in a navigation menu, but the picture displays are novel digital designs using albums, paginated grids, graphs, or clusters. As browsing and searching were the primary tasks being explored, none of them intend for an endless scroll of files and many even specifically seek to avoid one as the potential exponential growth of personal picture collections was a prevalent concern.

One early example of a forced order is Shoebox, even calling picture folders “rolls” [58], which clarifies the link between designs built on digital file systems and the film roll as a metaphor for digital picture interaction. Shoebox uses nouns detected from audio annotations to support searching and browsing, and includes a true timeline display with a forced chronological order of pictures along with other views with unclear ordering, but does not incorporate an endless scroll of pictures in a file system. Balabanović et al focus on storytelling from pictures, rather than searching or browsing, and create a tablet using a wired microphone and manual buttons with a user-ordered timeline of pictures to build stories either picture first or story first [6]. This use of a completely novel device as a setting for picture interactions avoids common computer designs, like file systems, altogether. As one of the earliest examples of a digital tool that focuses



specifically on storytelling, they do not incorporate different dimensions of data and focus on supporting a manual selection of pictures. They find that, despite the timeline view, the order of pictures was not used during storytelling.

These examples pre-date Frohlich's requirements for photoware and largely build on existing physical metaphors of album and film roll to explore the new digital space, while incorporating the new possibilities of digital spaces including speech interactions and automatic tagging. They do not incorporate existing digital standards of file storage or access for the actual display of pictures, but leverage the existing hierarchical folder structures for organization.

#### 4.2 Rising Use, New Digital Tools (2002-2007)

Starting in 2002, as digital pictures became the norm, research began to explore the established designs of desktop computers as the central setting for digital pictures while other works explored novel technology settings. With the rising use of the desktop as the digital picture setting, more novel designs include forced chronological orders as a central interaction with pictures. Similar to earlier works, these projects are often motivated by the intimidating size of personal picture collections and how users can better manage them. Calendar Browser and PhotoTOC both seek to support easier browsing of pictures by using time clustering to present groups of pictures on a scrolling timeline [35,66]. These scrolling timelines are perhaps the earliest examples of forced orders presented on scrolls and are also the first designs to be clearly based on the scrolling file system interactions common to desktop computers. This further strengthens the connection between standard digital file system interactions and the digital picture film roll metaphor that we first saw with the Shoebox "rolls" [58]. These works gathered users' own pictures and use targeted search tasks to measure browsability. In contrast to this, more recent work has found a targeted search to be distinct from browsing, which is less directed and often measures success not by an exact match, but by satisficing [89].

MyPhotos aims to simplify the more technical aspects of digital picture management by supporting picture curation with a partially automated process and merging that into browsing or viewing using a calendar view with grouped pictures [81]. As with the works in the previous section, this design employs familiar elements of file systems, but the display and interactions with pictures themselves are based on albums and calendars rather than a scrolling folder of files. MediaBrowser tries to encourage manual annotation by combining it into picture browsing and builds filtering tools onto an forced chronological timeline in order to support manual tagging [26]. There are several time-based views through which users can filter pictures based on their manual annotations within the forced order. Filtering is used in place of scrolling as pictures are scaled based on the total number included, presenting a novel alternative to either physical storage or digital file systems. TimeQuilt optimizes a timeline to fit on a single screen for browsing in order to address the problem of long scrolls of pictures in digital folders [39]. Again, we see the common overlap of the film roll metaphor and inherited desktop file system interactions with a standard forced order film roll metaphor adapted to avoid the scrolling. MyLifeBits builds stories from personal pictures (particularly from lifelogging cameras) using GPS tagging to present pictures on a map instead of a scroll or timeline [32]. The novel map-based interface avoids existing digital interactions, but the initial selection of pictures falls back on the digital default of file systems. These works all build on time ordering as the base for picture interactions, and control over ordering is rare, unlike the earlier works. The works with the clearest examples of film roll metaphors are also closely connected to the established file system interactions of desktop computers, continuing the trend seen in the previous section.

At the same time, other works create designs that present pictures linearly, but without a file system or a forced order by keeping the user in charge of picture curation and selection. PhotoArcs creates visualizations of user-ordered picture timelines in order to add a narrative aspect similar to in-person picture sharing [1]. iTell supports multimedia digital storytelling as an intentional and reflective authoring process with the manual addition of photos to the timeline

of an already written text [50]. These works consider incorporating narrative as a deliberate step of digital picture interactions and create designs based in narrative experiences, so the film roll metaphor is absent, the visual presentations are similar to walls or books with pictures, and the user is in control of the selection and ordering of pictures. This emphasis on authoring or curation as a human-driven step supports the flexible nature of reminiscence through enabling that browsing, but will still at some point require a manual selection of pictures in a large and growing collection, which may default back to file systems and film rolls, as we have already seen in other examples.

Other works began to explore different settings beyond a traditional desktop computer. Tabletops have been explored with personal pictures in several works that emphasize the collaborative and social nature of picture interactions, which is more available in a shared space than the more individual desktop computer. The Personal Digital Historian project uses a tabletop to support conversation and collaboration around photo viewing, including a timeline view along with browsing by map, person, and “free space” and is specifically designed without a “file&folder” display [79]. SharePic uses the DiamondTouch [25] to support older users specifically to collaboratively or parallelly create picture collages, based in observations of memory sharing [2]. SharePic follows the tabletop metaphor closely, so users interact only with pictures directly and there are no buttons, folders, or other computer-based elements or mechanisms. The Living-Room seeks to bring the experience of co-located sharing from physical pictures to digital spaces by avoiding the common desktop screen in favour of a tabletop combined with other devices to create a collaborative space for picture browsing and building “piles” of pictures [38]. PhotoHelix uses a tabletop to present a spiraled timeline (a forced chronological order) to support photo talk and the unstructured activities with pictures that surround it, like browsing [37]. This use of a forced order is uncommon to the early explorations of non-desktop settings and is used here similarly to early computer-based tools that build on a chronological order to explore novel digital interactions on top of that. Analog pictures on a tabletop reinforce the flexibility of their tangibility, and these digital tabletops often, but not always, continue to afford this freedom to the user. These works emphasize the collaborative and social aspects of picture interactions, and because of that, forced ordering is rare. Incorporating multiple users and a social setting seems to also consider the flexible and user-driven nature of browsing, leading to less structured formats.

Other alternative settings build on the familiarity of albums and frames. Jin et al create a digital album device (the GIA) in order to support the emotional aspects of pictures over retrieval tasks, and use user-ordered albums created by users from a timeline of all pictures [43]. Memento is a hybrid digital-physical album, based in observations of older adults using physical scrapbooks and focused on how those are used for reminiscence. The album uses a digital pen that expands on traditional scrapbook making with audio, digital pictures, and video, blending the digital and physical settings through a fairly literal application of an album metaphor [88]. Cherish is a digital picture frame that is designed to prompt spontaneous reminiscence by choosing which pictures to display based on various triggers, such as events and guests [47]. Durrant et al propose three speculative devices for picture display, all inspired by framed pictures and based around the interactive display of a random selection of a user-curated set of pictures [27]. Allowing for both “random” and chronological types of interactions, the different displays are designed to question the role of digital devices in casual picture interactions. As displayed pictures are already a source of spontaneous reminiscence, both the Cherish frame and these speculative devices seek to expand on that potential by adding a digital curation or mediation of pictures to the user-driven display. The projects using frames and albums explore how traditional picture media can be enhanced by digital settings, rather than creating something new, so focus on user curation of pictures. However, they often acknowledge that they cannot easily scale to include the size of a digital picture collection, which will only become more apparent as smartphones rise in use.

These formfactors that draw on familiar picture objects (tabletops, albums, and frames) are separated from desktop computers, and in these settings we see designs that draw further from those same metaphors, so file systems and film roll metaphors are rare. This is in contrast to the computer-based examples from this same time that either build on or incorporate the file system interactions that are becoming more and more familiar to digital spaces. The computer-based tools in this section largely use a forced chronological order, but non-computer settings largely contrast this with more user curation. The latter are often specifically exploring the collaborative and storytelling aspects of picture interactions, rather than the earlier emphasis on searching and browsing. During this time, the model of photowork is proposed which is based in desktop use and identifies event-based grouping without a timeline as the common organization strategy that should be supported by digital designs [48]. The next few years will heavily explore the desktop space and begin to build on the earliest examples of picture tools while incorporating modern capabilities.

#### 4.3 Common Desktop Use (2008-2010)

With family pictures being firmly established in digital settings, desktop-based tools heavily use timelines, but forced ordering is not as common as in today's tools. Pixaura is specifically for in-person sharing and uses interaction metaphors from in-person sharing to bring flexibility to user-created and interconnected albums, piles, bubbles, and auras of pictures [76]. This work emphasizes the tentative nature of curating picture collections and the close relationship between curating and sharing pictures. Taylor and Cheverst present a community display with pictures and categories added and managed by community members, giving them collective ownership over the display [83]. They investigate the potential for social interaction and connection around this public display and observe the resulting storytelling and reminiscence, similar to what is seen with family pictures in private homes. Like the earlier hybrid album designs, these focus on the shared experience of picture interactions and the user curation of pictures, and so avoid forced order presentations and file system metaphors.

Other desktop-based tools from this time build on the earlier search query tools and go back to focusing on the problem of managing and accessing large and growing collections. Camelis is designed to encourage users to annotate their pictures because that will enable its rich search structure and navigation [28]. It uses a hierarchical structure of pictures by various dimensions, including time, to enable detailed querying of pictures, which can itself be navigated for more flexible browsing within the hierarchy. Orii et al seek to support easier picture access by automatically clustering pictures by timestamps. This photo classifier uses a forced chronological film roll within each cluster and was assessed with timed directed search tasks, similar to the other search-based tools in the previous section [60]. These works continue to explore how to bring digital search capabilities to picture interactions within the default environment of the desktop, and focus on searching as the primary task to be completed.

Other research around managing large collections was considering different visual metaphors and more general browsing activities. Flux uses time as a dimension, but is based in actual use of physical pictures on a tabletop and combines automatically created "piles" of pictures with user made workspaces on an ordered layout to balance the needs of easy browsing and large collection size [7]. PhotoSIM brings more of the digital supports seen in professional picture tools to those for personal pictures through a graph-like display of pictures clustered by time and visual similarity. This machine clustering can be manually adjusted by a user or a new cluster can be made completely manually [21]. MediaGLOW extends this picture graph with more dimensions, such as location, in order to support easier searching, using a timeline as a supporting visualization of the search results [33]. Their assessment uses general search prompts for groups of pictures and measures how appropriate the chosen clustering dimension was to the given task, which more closely reflects the realistic use of pictures than the time to complete a directed search for a single picture. PhotoMagnets

explores flexible interactions with pictures through visually clusters of photos by similarity to one selected picture on various dimensions using a Dust and Magnet metaphor, as supported by a timeline of all pictures [22]. The evaluation of PhotoMagnets explicitly investigated how it could support storytelling through picture curation and manual album creation. Many of these projects are intentionally building on actual physical picture interactions and incorporate metaphors from those. Though time continues to be a dominant data dimension for picture navigation, a forced order presentation of pictures is not common and user control and curation are intentionally included. As we saw in the earlier examples that drew on physical interactions for formfactor (e.g., digital tabletops), these designs that bring those metaphors into the desktop setting lack both film roll metaphors and file system designs.

Alongside the rising popularity of the desktop setting, some works continue to explore alternative settings, including incorporating early options for tablets. The Flutter digital picture frame creates enjoyable viewing experiences from large picture collections without the need for intentional browsing or searching tasks through unstructured exploration [90]. They use a simple display, similar to a tabletop of pictures which can be navigated by shaking the tablet or by interacting directly with pictures using a stylus. Souvenirs combines digital and physical heirlooms to improve the accessibility of digital pictures and to create more opportunities for sharing and reminiscence from digital pictures [59]. Using RFID tags, tangible artifacts in a home are linked to user curated sets of digital pictures, which can be displayed on a nearby screen. The curation and linking steps are separated from the scanning and sharing activities, and initial selection of pictures does use the default desktop interface. These examples use tangible tools and interactions, building on familiar public displays of pictures, like picture frames, to foster the social setting of storytelling with digital pictures, but encounter some limitations in the connections between picture storage on a computer and interaction with the novel devices. This may be because they have been designed as separated steps; the separation of database (storage) and narrative (interaction) that is common to digital settings, but not to picture interactions.

With the rising availability of camera- and smartphones, picture interactions become more closely tied to the camera with capturing, browsing, and sharing becoming easily possible on the same device. Early explorations of phone-based picture interactions focus on the new device's limitations. Zurfer is an application that explores the potential uses of digital pictures on mobile phones and uses the metaphor of pictures kept in a wallet to support basic access through automatic or user-curated "channels" of pictures [40]. Users shared pictures on this to start storytelling, just as someone could with the select few pictures that were often kept in a wallet. StoryBank is a digital storytelling platform that uses pictures to create stories in communities with low rates of literacy. Users can manually select and order pictures to create short, visual stories on smartphones that are shared on a community display to share narratives and important community information [30]. Similar to designs from physical metaphors, early camera phone design was separated from desktop design norms, so norms of file systems were not inherited. Additionally, a limited collection size was necessary for early phones to be able to display pictures at all, so these examples rely on user curation. As phone storage increases, these limits will be all but removed and replaced by film roll scrolling.

During these years, domestic photography has become nearly entirely digital, and smartphones are just starting to be explored as a novel picture interaction setting. There is still a range of novel designs with a range of interactions and metaphors, several based in physical pictures like a tabletop or wallet. The motivations of this research are consistent with the previous sections; managing and navigating large and growing picture collections are the primary concerns, but storytelling is also becoming more common as a stated motivation. A clear divide is starting to emerge between the designs that are built within the standard file system interactions and those drawing from physical metaphors or novel settings. This divide also clearly parallels the presence of (and dependence on) the film roll metaphor: computer-like

storage creates film rolls, while designs that focus on social picture interactions do not draw from broader expectations of computer storage and interaction, and so avoid the film roll metaphor.

#### 4.4 Settled Design Standards (2010-2019)

In the past decade, there has been less research into novel digital picture interactions. The design space is seeming settled and some more recent designs use strong film roll metaphors. 4Streams is described as a “visual Twitter feed” that supports ambient social connection by combining four users’ picture slideshows together with real-time updates on a shared screen with synchronized chronological viewing of their pasts [93]. This is designed as an extension of or a response to picture use on social networking sites, not pre-existing physical uses, so it inherits the film roll metaphor for the immediate sharing use case that is prevalent to those settings, instead of the endless film roll from desktop file systems. The Chronoscope is a telescope-like device that considers how to browse a film roll and incorporates tools for flexible exploration within that metaphor, including viewing pictures from the same day across different years and the same time across different days [20]. These projects are intentionally based in existing film roll formats, bypassing the influence of desktop file systems and explore interaction with that metaphor rather than including curation or unstructured browsing from physical settings.

Others, continuing to explore the ever-present problem of managing large picture collections, include one element that employs the film roll metaphor, often on top of but separate from the main interaction. Jónsson et al use a three-dimensional cube to visualize subsets of picture collection and to support organizing and browsing those pictures using various dimensions, including time [44]. They assess the browsing capabilities of this design through a mix of targeted searches and open-ended browsing tasks. Ott et al present a variety of options to bring viewing and enjoyment of pictures into digital picture management, including a cube-like chronological display, extending a film roll metaphor, and a manually ordered photo “path” intended for curated storytelling [61]. The display is designed to look like a room, so the film roll elements are not built on interactions with file systems. Zurn et al explore ways to support and inspire curation of large picture collections on a smartphone, building on the existing scrolling film roll of that setting, through voting on random comparisons and a grid film roll that scales each picture based on its cumulative votes [94]. This is the first smartphone-based example after large-scale picture storage and access became available. As seen in rising desktop use, this design builds on the existing interactions with photo galleries and slideshows that themselves were inherited from desktop file systems. They observe that reminiscence is a natural side effect of this prompted curation, which is further supported by the PhotoUse model. The large size of digital picture collections without clear and easy access to them continues to be the main motivation for picture interaction research across this history. Recognizing that time is a significant identifier for pictures (and for digital files generally) [77,89], these works combine that with more flexible interactions, inspired by the motivations to support browsing within large collections.

Some recent works that lack a strong film roll engage with users directly in the curation of their pictures, including through physical or tangible designs. 4Photos incorporates physical interaction with digital pictures to encourage phototalk. This spinning device sits on a dinner table showing photo “strips” that users have curated from their collections [84]. This is another project with on a novel device that draws from the immediate sharing use of the finite film roll, rather than the endless scrolling version from file systems. Pearl projects a collage of pictures on a wall to support viewing from large digital picture collections similar to physical pictures in frames [41]. Users are encouraged to engage with and curate the pictures in a variety of ways: unwanted pictures displayed in a college can be deleted, and less seen, forgotten pictures are faded out until they are interacted with. Piper et al create a digital-physical hybrid album to support the continued socialization of older adults and their families by combining the familiar physical setting of a

paper album with the new digital capabilities of audio recording [64]. Breokhuijsen et al suggest several designs for collocated reminiscence from digital pictures, based on their previous research revealing the need for user curation, including a hybrid album and a group of blocks that can be rearranged to create a collage [13]. All of these works present designs separated from desktop (or mobile) norms, and so have not inherited its endless scroll in the form of a film roll. Where a film roll is present, it has been intentionally included in the novel immediate sharing that has emerged from social networking sites.

Other recent research that emphasizes user curation over forced ordering uses ubiquitous screen-based devices and often focuses on a specific social setting, like a family calendar or a community with limited communications infrastructure. Jesus et al build photo annotations from users' spoken descriptions over user-created slideshows to support search and retrieval tasks, and uses a file system-based navigation menu, showing that the problem of large collection size has continued to be prevalent after two decades and continues to be considered from the point of view of computer storage [42]. MultiMediaNarratives supports existing narrative activities on camera phones, based in oral history traditions, and considers the needs of the limited communications infrastructure. Users curate their pictures to create audio-picture narratives slideshows that can be shared across communities through Bluetooth [31]. Frame of Mind presents a tablet app designed for picture reminiscence that highlights the need for free-flowing (unordered), contextual picture interactions more like those on a physical tabletop, as informed by observations of actual physical and digital picture use [3]. Tojo et al explore reminiscence as a central aspect of family socialization and bring the flexibility of user-curated collages onto a calendar interface for generations of family to build and share stories together [86]. Again, these designs are approached from a non-computer perspective (i.e., calendars, oral storytelling, family dining tables) and all of them lack a file system interaction or a film roll metaphor.

An exploration of interactions with "duographs" uses smartphones to create a particular type of digital picture made of simultaneous pictures taken by both front and back cameras on a phone (e.g., a selfie and a more traditional snapshot), and explores different methods of interacting with those two-sided pictures to support storytelling and sharing [36]. This work has no connection to file system storage and does not investigate user curation or access to large collections, because the novel nature of these pictures means they are part of a small collection of just duographs and are unique to these devices. Instead, it explores what can be done with the digital setting of pictures across domains of use including capturing, viewing, and sharing all in ways that were at best impractical before the availability of smartphone cameras.

User engagement with pictures, especially curation of their pictures, is a key aspect of non-film roll interactions, and has been identified by past works [3,12] as absent from available digital interactions. Many of these recent works create this space for user curation and engagement, often drawing from existing physical interactions as metaphor or from recent observations of actual use of pictures rather than digital design norms like file systems.

#### 4.5 Historical Takeaways

Research has proposed few novel designs in the past decade, but offers many explorations of actual use, especially of social media [53,65]. Thomas and Briggs propose a method of transforming Facebook posts into a printed book for the purpose of reminiscence [85]. Pensieve prompts users to document reminiscence in a digital diary by regularly sending pictures from linked social networking accounts [62]. These tools explore opportunities for reminiscence within the existing frameworks of social networking sites, which otherwise do not easily support reminiscence, as we explore in depth in the next section. They are built on social networking platforms (the narrative of digital pictures) and do not connect back to the storage aspects of computers and cloud backups (the database of digital pictures).

The lack of novel design research suggests a stability of accepted design; that the design of digital picture interactions is currently settled and perhaps that the “era of ferment” discussed by Sarvas and Frohlich [74] is ending. However, research into modern use continues to show that digital interactions are not supporting desired use [13,29,77,89], which we propose is heavily influenced by the prevalence of the metaphorical film roll outside of its normal role of the analog process of physical pictures. Despite the popularity of the film roll metaphor in commercial settings, HCI research has proposed a variety of designs with and without this metaphor, without a clear preference in these novel designs over time.

Throughout this history, we have shown that use of the film roll metaphor is tied to use of file systems as the default method of storage and access on computers. As digital pictures are inherently digital files, it is simple to incorporate the existing systems for handling those files into the systems specific to pictures rather than create new and separate interactions just for this type of digital file. This is the explanation for how the film roll has become the default and dominating metaphor, despite the continued variety of research: the path of least resistance, the established digital default, was created for the needs of computers over social connections and because it was already established for broader use, it could easily be seen as the logical interaction.

Figure 2 shows our proposed timeline of works that we discuss in this section as well as the frameworks of use discussed in the previous section. This visualization demonstrates the bulk of works that have considered how to best or better interact with pictures, though it has been noticeably waning in the recent past. While these works have continued to propose new interactions, others have continued to try and understand what we are doing with digital pictures and how that is supported or hindered by digital tools.

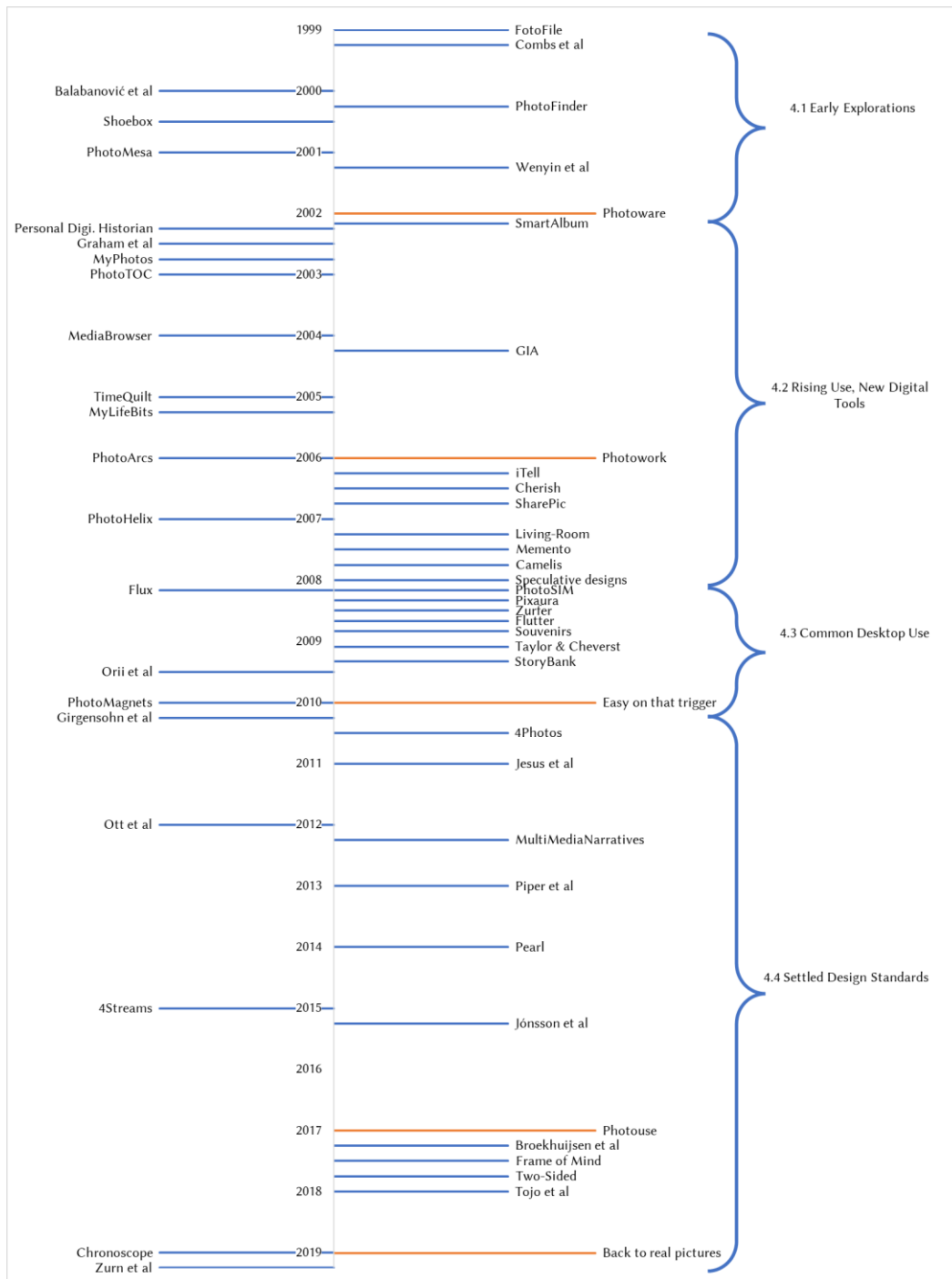


Figure 2: Timeline of digital picture design works (blue), those largely using film roll metaphors are to the left and without are to the right. Reviews of use or requirements (orange) are to the right. The curled braces to the right align to the subsections of section 4.



The subsections on the timeline show how the research peaks as a prevalent topic as digital pictures are becoming the norm for all domestic photography (4.3 Common Desktop Use) and begins to wane across the following decade as the available designs seem settled. But the wane in novel designs is not reflected in the works seeking novel understandings: they are continuing to refine understandings to consider emerging uses of social networking, but they also confirm the findings of their preceding works that reminiscence is still absent or at best inconvenient in the available setting. These works are pushing back against the strongly established expectations of digital storage.

By following the patterns of design and metaphor use across this research history, we are able to identify the historical origins of the film roll metaphor as accepted norm. With this understanding, we can now question its modern use. In the next section, we outline the extent to which the film roll metaphor has permeated digital picture interactions, particularly browsing and other retrieving activities. The included systems are no longer built directly on top of file systems, as many of the historical examples were, but have nonetheless inherited the film roll from there. Through this investigation of actual interactions with digital pictures we highlight how this metaphor is misplaced and misused across the processes. We then contrast that with the research history presented above to reflect on future designs and the importance of intentional metaphor design.

## 5 FILM ROLL METAPHOR IN DIGITAL PICTURE INTERACTIONS

To ground our exploration of this metaphor, we conduct a perspective-based inspection [91] of the digital picture interactions of the primary picture tools for both social networking and cloud picture storage with a specific view to how the film roll metaphor manifests across them. As a usability tool, perspective-based inspection evaluates different aspects of a given interface (or several interfaces) by focusing on different perspectives. The goal of this method, as with other usability evaluations like heuristics evaluation, is often to identify usability problems or issues, but is also used to identify how design elements are used more generally. We use a perspective-based inspection to take on the perspectives of a user posting or uploading to a given tool (a “poster”) and of a user passively viewing or browsing pictures (a “viewer”). These different perspectives allow us to identify the presence of the film roll across various picture tools.

To support the inspection, we use the PhotoUse framework [12] to ensure we capture the variety of digital photo activities. This framework is necessary in order to guide the observations, as has been found in similar analyses of use [51], especially when the population and actual use is not well understood by the research field. First we describe the PhotoUse framework we have chosen to use and why we chose it. We then outline our findings and trends in film roll metaphor use across these tools and present two scenarios highlighting how the film roll impacts use. In the next section, we combine this understanding of modern designs with the historical perspective from the previous section to present the effect of the film roll metaphor on both traditional and novel picture activities, as well as how those historical designs can be brought back into consideration for modern use.

### 5.1 Data Collection Framework

As discussed in the previous section, many works have looked at the variety of activities people do with pictures. We choose to use the model of PhotoUse proposed by Broekhuijsen et al [12] as it is a detailed and recent model of picture use and describes the broad potential paths that people can take through these activities while engaging with their pictures (see Figure 3). The PhotoUse model identifies four major types of picture use, each with two to four activities:

- **Accumulating** by either taking new pictures or collecting pictures taken by others,
- **Curating** the collection of pictures through activities like editing and organizing,
- **Retrieving** pictures by actively or passively looking for them, like browsing, and

- **Appropriating** pictures by modifying them and sharing them with others.

We include the full definitions of each of the activities of the PhotoUse model in Appendix B for the reader's convenience.

We choose this framework for the level of detail in activities provided. Several other models or observations of picture use (both physical and digital) mirror key components of this framework [4,48,68]. We use this framework to guide the perspective-based inspection to include the breadth of tasks that make up digital picture interactions and to identify the use of the film roll metaphor in each of those. This does not ensure that all the possible ways to complete a single activity in the model are included, but allows for the scope of the activities to be well-represented.

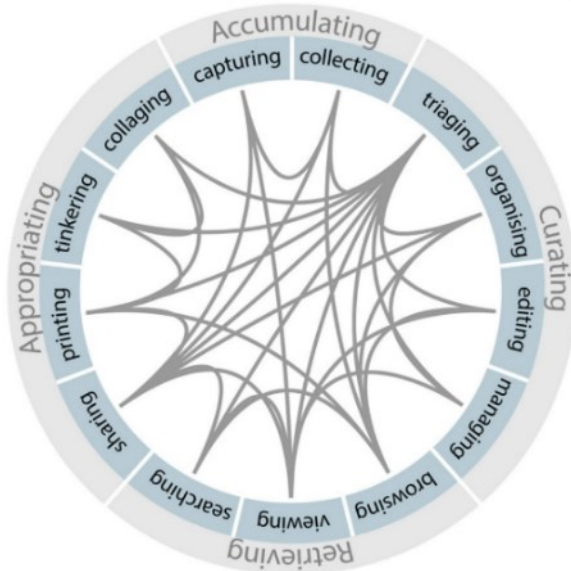


Figure 3. Model of PhotoUse proposed by Breokhuijsen et al. as published in [12].

## 5.2 Data Collection and Coding

To include the broad applications of pictures across digital tools, we include in our data the three most popular picture-based social networking sites in North America: Facebook, Instagram, and SnapChat [63]. We also include the four most popular photo cloud storage tools (Google Photos, Apple Photos, Microsoft OneDrive, and Dropbox) again in North America [78], though measuring popularity or use of cloud tools for pictures specifically is made difficult by the majority of smartphones having either the Google or Apple tool installed and used by default. Finally, we include Flickr as an example of a long-lasting photo-based tool that merges cloud storage and social networking motivations [57]. These eight tools provide a representative view of common picture interactions across digital spaces, though there is also a broad range of lesser used tools, as seen in the previous section. Our intent is to reveal the extent to which the film roll metaphor is present in prominent tools and common use, thus we focus on the most common tools. We have chosen popular tools in North America, as we are based at a Canadian university, knowing that this excludes tools popular in other areas of the world (e.g., Baidu cloud), and future work can extend this analysis to include a broader selection. Appendix C lists the included tools with the platforms and versions used for coding.

Before coding began, we (the first two authors, both experienced HCI and media design researchers) created a preliminary codebook with common types of scrolling and ordering, which remained unchanged. These were derived from the common implementations of film roll metaphors. During coding, we iteratively added types of order control (whether the user can control how pictures are ordered) and two additional codes for corner cases of the film roll metaphor: first, activities that do not use a film roll metaphor but cannot be accessed without first interacting with one, and second, activities that included a timed deletion mechanism (such as SnapChat). The complete code book is in Appendix D.

The second author conducted the data collection as an expert user of all of these tools (i.e., daily or near daily use of the tool for activities of domestic photography), with the exception of Google Photos which was collected by the first author as a more expert user of that tool. We use a single coder as the data (e.g., presence of a picture scroll, sort order) are clear and would not be helped by additional researcher input [55].

Each tool was coded individually from the perspective of both a poster and a viewer, and both web and mobile versions were coded separately when appropriate (e.g., Instagram and Snapchat are mobile tools with significantly limited web-based interactions). For each of the PhotoUse activities (see appendix B), the researcher found as many ways as possible in which a given tool supports that activity, if any. We did not include activities that could only be completed by leaving the tool (e.g., printing a Facebook picture to a local printer through the print feature of a web browser is not included under the printing activity).

While it is possible, and even likely, that this process did not capture the entirety of how all activities can be completed across these tools, it does identify the ones that are amplified by the tools' designs and are known by most users. Previous work has shown that there is a wide variety in how these tools are used. Our intention is to highlight what is easily or intentionally made possible by the designs of these common picture tools. We do not identify the activities themselves within these tools, but the areas of these tools that support or encourage those activities. A user is able to share a picture by one of several paths through various mechanisms. A given mechanism (e.g., post picture) could be included across multiple activities, and a single activity could be found in many distinct areas of a tool.

For each of the identified applications of the activities, the researcher then identified the presence and impact of the film roll metaphor, as defined in section 2.1, and coded them accordingly including the scroll, order, and order control. This resulted in a list, for each tool, of actions that can be taken towards each of the PhotoUse activities by both poster and viewer and how those pictures are presented and accessed.

### 5.3 Analysis of Photo Tools Through the PhotoUse Framework

From the coded tools, we collected counts of the actions included under each activity and how many of them used a forced order (no user control over the order of the pictures), a chronological order (pictures default to a strict timestamp-based order), or a forced chronological order (no user control over the strict timestamp-based order of pictures), as well as how many do not directly include aspects of scrolling or ordering, but are accessed through a film roll (i.e., a scrolling view with a forced order). Aspects of the tools that both do not have a forced order and can be accessed without navigating a forced order do not use a film roll metaphor. See Appendix E for examples of all activities of the PhotoUse model 19ssocis the included tools.

Table 1 summarizes the presence of the film roll metaphor across the four types of PhotoUse activities (described in Figure 3 and Appendix B) as demonstrated by a forced order (especially a forced chronological order), as well as activities that are only accessible via a film roll. In all the reviewed tools, film roll metaphors are the prevalent interaction across retrieving activities. Curating and Appropriating activities had less direct film roll interactions, but are still reliant on

the metaphor as most activities could not be done without accessing them via a film roll (e.g., to edit a picture it must first be found in the camera roll). Accumulating activities, the area where the film roll is literally present in analog photography, has a mix of film roll interactions (e.g., adding pictures shared by others to a collection of favorites), ones accessed via a film roll (e.g., downloading a picture from a shared album), and ones without it (e.g., taking a picture within the app). As seen in Table 1, very little is excluded from the film roll metaphor. In retrieving tasks, which includes browsing, only 11% of activities have no forced order and can be accessed without navigating through one.

Table 1. Distribution of forced and/or chronological order designs, those accessed via those metaphors, and those without them across digital picture tools by the types of PhotoUse activities.

Activity Type	Forced Order	Chronological Order	Forced Chrono. Order	Access Via Film Roll	Without Film Roll*
Retrieving	84%	63%	57%	5%	11%
Curating	24%	31%	20%	65%	11%
Appropriating	22%	23%	20%	75%	3%
Accumulating	64%	52%	52%	32%	4%

\*Design aspects without a forced order and not accessed via a film roll metaphor can be completed without a film roll metaphor.

Across these tools the presence of the film roll is seen in the form of forced order, and more specifically forced chronological order, picture presentations. This is especially present in the three retrieving activities (browsing, viewing, and searching), as seen in Table 2. As we discuss in the next section, this prevalence of forced order is particularly significant in the retrieving activities as these are the access point to all our pictures, especially through the central camera roll of all pictures.

Table 2. Percentage of the different retrieving activities that use forced order (forced chronological order in parentheses) across surveyed tools.

	Instagram	Facebook	SnapChat	Apple iCloud	Google Photos	OneDrive	DropBox	Flickr
Browsing	100% (25%)	100% (57%)	100% (75%)	69% (63%)	80% (53%)	100% (67%)	100% (60%)	88% (13%)
Viewing	100% (100%)	100% (100%)	100% (100%)	70% (40%)	90% (70%)	100% (67%)	100% (60%)	88% (13%)
Searching	75% (75%)	75% (25%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)	100% (33%)

The primary takeaway of this investigation is confirmation that the film roll metaphor is present throughout our interactions with digital pictures. Particularly when retrieving pictures (that is, activities like browsing that are key to accessing pictures specifically as memory prompts), there is very little opportunity to avoid the film roll metaphor. This is in contrast to the historical view presented in the previous section where the film roll was certainly present, but not dominant, as research has been consistently exploring what can and should be done with the designs of digital picture interactions.

Given that the relevant research does not indicate a need or preference for this metaphor and shows that current options are not sufficient for the range of actual picture activities, the extent of this metaphor across available tools and areas of use needs to be questioned and better understood. To further explore the reach and implications of this metaphor, we present two use scenarios that highlight navigation through the film roll metaphors, and some exceptions, that reveal motivations in the designs of these tools. In these scenarios, the relevant PhotoUse activities are identified in square brackets (e.g., [browsing]).

#### 5.4 Scenario 1: Google Photos Album

April wants to put together an album of pictures of her young adult children as babies to reminisce on the good memories made many years ago. On her computer, she scrolls through the thousands of pictures in her seemingly endless Google Photos camera roll [browsing]. Each time she sees a picture she wants to save, she selects it [triaging], sometimes adds a filter or crops the picture [editing], adds it to the album [organizing], and then returns to the camera roll to find the next picture [browsing]. She carefully curates the album by moving photos around into the order that she would like to share these memories [organizing]. Once all these photos have been organized and edited, April emails a link to the entire album to her mother [sharing]. Her mother replies to say how much she loved looking back at the pictures, and April opens the album again [viewing] to order a printed book [printing] to share with family in person when they next visit.

This album works very much like a physical one. Pictures are chronological by default, as they would be in the envelope of developed pictures, and can be rearranged as desired by users. They mimic the physical format, easily shared as a whole with other people, though the social activity of reminiscence is less present without a way for people to interact together over distances, especially through storytelling. Linking the digital album directly to the creation of a printed picture book further reinforces the album metaphor. The process of creating the album though is still tied to the endless forced order scroll that is so difficult to browse.

This cycling from digital albums into physical ones and from physical metaphor into digital spaces, reflects the lifecycle of pictures that must be captured, developed, and shared again for each new picture. Within a task-artifact cycle, these are caught between the new possibilities of the digital format and the old requirements of the analog system, namely a film roll [17]. Google Photos includes the possibility to remove the manual work of creating an album by using automatically created and automatically updating ones, such as based off a recognized face, and by searching by any number of dimensions including abstract concepts like “fun”. However, every step away from the manually created album is again a step towards the film roll as each of these options are presented in a forced chronological order. As new possibilities are brought in (e.g., facial and image recognition, geotagging, capacity for seemingly endless collections), the old expectations of easy browsing and selected subsets of pictures are set aside.

#### 5.5 Scenario 2: Instagram Story

John uses Instagram to keep updated with his friends' life, as well as share snippets of his own life. When John first opens the app, he is met with a forced chronological order scrolling feed showing what people on Instagram are up to. While waiting for his morning coffee, he scrolls through this endless feed [viewing] and then checks a friend's Instagram Story to see the ten pictures they have added, so far today, to the slideshow of curated snippets of their day that will be deleted after 24 hours [viewing].

Once he gets his coffee, John decides to take a picture of his coffee through Instagram's built-in camera [capturing], add a filter and some stickers to this new picture [editing], and post it on his story [sharing]. After 24 hours, John's coffee picture disappears from his story, along with his other story posts from that day [organizing], but he still wants the coffee picture to be viewable by his followers who might have missed it. So, he opens his profile, scrolls past his other deleted story posts [browsing] to find and select the right picture [triaging], and adds it to his 'highlights' [sharing], joining all his other coffee-related posts that he has accumulated throughout the weeks [organizing].

Instagram stories are not albums meant to last and be passed on. They are a new idea for this new space of immediate sharing. The short time frame of availability creates an ephemeral space for this sharing that reflects the immediacy of the activity. A picture that is to be shared now does not need to be seen next week or next year. This immediate sharing

brings people together over a picture of a moment as they could experience a moment together in person, such as over a cup of coffee. This motivation is completely distinct from that of a physical album, and research has begun to explore its use as popularity of this deleting feature rises [8].

### 5.6 Intended Metaphor of Digital Picture Interactions

Digital photography has broadened the popular uses and motivations for domestic photography, as has been seen across past research, and the Instagram scenario in particular highlights the common immediate sharing motivation of social networking use [73]. This is contrasted to the more traditional album, for later reminiscence, as seen in the Google Photos example. This album example, however, is the outlier of digital use. Most interactions, including on Google Photos, is through forced chronological order, often on an endless scroll, including building the album.

From the in-depth presentation of historical research, we show how this film roll metaphor is closely connected, and likely inherited directly from, digital file systems as the norm for visualizing and accessing digital storage. However, the tools presented here are only tangentially and often momentarily connected to those files systems (e.g., during bulk upload). Though digital pictures have become less and less connected to personal, local storage and have moved to clouds, our interactions with them have continued to incorporate the film roll as the assumed norm of picture interactions, maintaining a forgotten (and superfluous) connection back to those early file system designs.

## 6 CRITICAL REFLECTIONS

From our investigations of both past research and modern designs, we now can present our understanding of how this metaphor interacts with the activities that are regularly done with pictures and reflect on the future of picture interactions with and without a film roll metaphor.

From the historical perspective, we reveal the shifting patterns of design trends as well as the impact that the rising use of a film roll metaphor in available tools (as inherited from file systems) has had on the research space. We choose to focus on HCI research that proposes a new tool for picture interactions, not a standalone algorithm or other design aspect, so this does not represent the broad scope of picture-focused HCI research, but presents a detailed view of what was being considered for the design of digital picture interactions over the relatively short history.

From the investigations of available tools, we see that the large majority of ways pictures are presented or can be accessed is either on or through a film roll. We did not gather actual use and intentions from participants, as past works have done (e.g., the PhotoUse model [12]), and instead focus on the designs of the tools themselves. Through this, we identify the aspects in which the film roll is present and what areas of picture use (e.g., browsing, editing) can be accomplished there. Past works have shown that people do not find reminiscence to be supported by digital pictures and the associated digital tools [13,29,77,89], and we build on that knowledge to investigate where the designs fall short for reminiscence, based on the historical perspective.

In this section, we start with a discussion of the camera roll as the central access to all our pictures, followed by each of the two major social uses of digital pictures: reminiscence in the long-term and immediate sharing in the short term, and end with a reflection on picture uses by people and by tools.

### 6.1 The Influence of an Endless Film Roll

Our findings, as well as those from past works exploring modern use of digital pictures, show that the current use of the film roll metaphor as a key aspect of picture interactions is contrary to social reminiscence. Pictures are not easily found when continuously scrolling by date [13,89], but are better remembered by event or other more general identifier,

as seen in the common event-based storage styles of both physical albums and digital file systems [77,89]. Due to the various mixed applications of smartphone photography, captures for later reminiscence are presented alongside those for immediate sharing. This contributes to large and growing picture collections that are overwhelming to maintain, with no clear support for that maintenance in digital tools [4,13,77,89]. Looking back to the early explorations of our use of pictures, which focused on traditional reminiscence activities over immediate sharing (as it was not yet as present or understood), their findings emphasize the importance of user-guided browsing and shuffling type activities over timeline scrolls [29]. Previous works have shown that digital tools have not and still do not support reminiscence [5,13,29]. In this paper, we indicate the film roll as a key cause of that and show its origins in digital file systems. Despite this consistent finding, modern tools continue to rely on the film roll metaphor especially for browsing a complete collection or feed, as seen in our investigation of modern designs. While research has continued to show that a digital setting could enhance picture browsing and reminiscence, the prevalence of the film roll metaphor has blocked that. Because of this, it does not seem that digital picture interactions have had the chance (with regards to narrative) to be pushed to the limit and then reverse their modalities [56].

This lack of control over the presentation of our own pictures, representations of our own memories, is new to digital spaces. For a picture to act as a prompt, it must be seen. When pictures are presented in endless scrolls with little method to manage the endlessly growing and overloaded collections (made possible by the digital), meaningfully seeing individual pictures is impractical. Access to curated settings like Stories and albums is still mediated almost exclusively through the endless and growing scroll. The daunting problem of growing digital picture collections has been a major motivation of digital picture interactions research across the past two decades, as our historical perspective has shown. However, this remains a prevalent issue, which is exacerbated by the film roll. There has not yet been a wide-spread design response to this problem that tackles the browsing itself. Instead, interactions, like adding to curated albums or Stories, are built off of the scrolling film roll, requiring users to find their way through that first.

This film roll of all pictures is practically the sole access point to our pictures, regardless of intended purpose. As such, all our interactions with pictures are modified by this metaphor, including the common overwhelmed feelings when faced with the scope of work to catch up on [12,52]. **This is the main influence of the endless film roll: lack of control and lack of motivation.**

The historical perspective of HCI research provides the necessary context to understand the impact of the film roll metaphor on the design of modern digital picture tools. The variety of proposed designs and the different motivations of these works, many of which are still unresolved, shows that the use of this new media is not well enough understood to be stable, despite the seeming stability of generally available designs. The film roll design was not created for digital picture interaction, but is an adaptation of digital file systems onto a photography-based metaphor. This metaphor has not moved through the Laws identified by McLuhan [56] and is stagnant. Despite this, the designs of available tools continue to push ahead with new options, all placed on or around the film roll. Broad-reaching metaphors like this one should be continually questioned and investigated by designers in order to understand how it is serving use of the broader tool and how people are impacted by its influence. A detailed historical perspective allows researchers to build this understanding, determine its origins, and demonstrate whether it is actually a well-placed metaphor.

A digital metaphor can be an extremely powerful tool, as seen in ebooks, for example. A strong metaphor can be a bridge between old and new use or old and new media, supporting the processes seen in the task-artifact cycle [17] and the Laws of the Media [56]. However, a metaphor is only effective when the role of that metaphor within both the process inspiring it and the novel setting has been thoroughly considered, including the potential impact on both existing, expected use and predicted novel use [80]. Within the task-artifact cycle, a metaphor must be able to evolve

with the expressed needs of users, but also needs to come from that same motivation of supporting user needs. Our exploration of film roll metaphor here has shown how it does not meet any of these expectations and has come from digital design choices that were established distinct from and well before the rise of digital pictures.

## 6.2 Digital Social Reminiscence without a Film Roll

The metaphor of a roll of film applied to the viewing and browsing of all photographs together is misplaced. The film roll is rarely, if ever, interacted with by a domestic photographer. Instead, folders, boxes, and especially albums of pictures are the access points for browsing. Past research has proposed many designs that take inspiration from these tools across the past two decades, particularly as digital picture interactions became generally available. However, these have not been brought into commercial or otherwise available tools. Some historical designs use a direct album metaphor by grouping pictures into books that can be viewed individually, such as the digital album proposed by Jin et al. [43]. Others build on the motivation of an album, namely high-level organization through one or several dimensions of data, which could include chronology, to support searching and browsing smaller sets of identifiable pictures, such as the MediaGLOW graph [34] or the PixAura bubbles [76].

This high-level browse or satisfice (as identified by Whittaker et al. [89]) is so central to picture interactions that users must navigate through film rolls even for tasks that do not inherently require it, such as deletion or editing; a picture must be found before it can be removed or changed. The prevalence of endless forced order scrolling across these interactions limits the space for social reminiscence, as those interactions are fostered by casual, collaborative, person-controlled interactions rather than app-dictated orders.

As with any underexplored digital space, there is likely an infinite variety of interactions with pictures that could better include reminiscence than the current film roll, as seen in the variety of the research history of this area. Previous research has included graphs, cubes, and collages. However, we show in the review of previous research that the age of ferment for digital picture interactions is likely ending [74], meaning the film roll metaphor is seen as settled and accepted, so there is less novel research that diverges from that. Because the purpose of this paper is to reveal how the underlying metaphor is underdeveloped, we discuss here the album as a potential source of design metaphor that has not been considered nearly as broadly as the film roll has, despite being present across the research history of this area. Future work can expand or diverge from this exploration to consider other metaphors or interactions that intentionally avoid analog metaphors. First, we look to develop the potential of a digital album metaphor that could be as far reaching as the film roll is now.

We see that album-based metaphors would better support this browsing than a film roll can, from both the known user difficulties navigating endless scrolls [13,89] and past research into album-based tools [29]. In terms of the broader metaphor of film photography, an album is the appropriate point of the process to build on, when a film roll is already past its usability. A physical album gives picture collections a customizable high-level organization with a limited set within each album, so that both the high and low levels can be scanned quickly. Digitally, an album metaphor can encourage various dimensions for high-level browsing across a large collection through sets or associations of pictures before a closer viewing of that set. This removes the endless scroll of individual pictures in favour of navigation guided by the user during reminiscence. As seen in the scenarios above, not all picture interactions are motivated by reminiscence, and we discuss immediate sharing in the next section. However, as user motivation pertains to browsing, once someone is scrolling past today's pictures, the intention is more likely reminiscence than in the moment sharing, further supporting the need to consider reminiscence in designs of retrieving activities.



A digital setting does not need to mirror the analog picture process that came before, and accurately following that process is not automatically best for users and usability. Continued explorations of reminiscence picture interactions will likely identify options that deviate completely from what is done now with analog or physical pictures. However, research into truly novel options is currently limited and the easily available tools to users are stable in their reliance on the film roll, as seen in our design investigation. Given the lack of opportunity to experience the album's potential in a digital space, as we have physically for well over a century [72], we propose that this is a key step in the continuing history of our interactions with pictures.

**The history of the design of digital picture interactions has clearly shown that an album metaphor creates space for social reminiscence.** The past digital examples show us that use of an album metaphor can be much more broad than the physical form factor; many options do not have a page to turn or a book to select. Rather, they highlight the aspects of albums that have allowed them to persist throughout more than a century of domestic photography: organization at a high level that is chosen and interacted with by the user(s). Several of the previous research works have shown how browsing can be enhanced digitally through, for example, speech interaction or semi-automatic organization, which has the potential to obsolesce the one-dimensional organization of pictures in albums or boxes in favour of more flexible options for browsing and retrieval.

It is from this historical perspective that we are able to see the overlooked potential of this metaphor and compare it to what is available now. From these examples, we see that an album metaphor has better potential to support continued and novel use, and follow McLuhan's Laws of the Media [56]. Similarly to the previous point, we see that a digital metaphor can be limited by how it is applied. A film roll is a central aspect of analog photography, but is not a logical choice of metaphor for browsing because that was not the intent of that tool. This misplaced metaphor is leading the rest of digital picture interaction design, rather than a design being informed by the metaphor [80]. An appropriate metaphor takes the full scope of a given process into consideration, alongside the expected use in the novel setting. While the symptom, lack of reminiscence, has been identified for some time by qualitative research, little work has been done to identify and address the cause. With this work, we first investigate one potential cause, then clearly show its impact on use, and now we propose an alternative. Researchers can follow these steps to respond to an aspect of design that is lacking by identifying both the symptom and the cause, and then determine how to respond through a deep understanding of the relevant research history.

In our work, the history of HCI has demonstrated what could be done with the album metaphor. Available digital picture tools now need to build on that so we can understand the actual use of this metaphor. Generally, we need to keep exploring and proposing new options, alongside understanding how the current ones are being used. Future work needs to focus on picking up where past research has left off to continue the work of exploring reminiscence with digital pictures as a novel medium rather than a settled and accepted design.

### 6.3 Immediate Sharing on a Film Roll

Social networking has fostered a modern kind of picture interaction, made possible by the instant access to and sharing of a newly captured picture, as seen in the Instagram example in the previous section. Instagram Stories, and other interactions that are ephemeral in their design, support this novel use through a film roll metaphor. Here a forced chronological order is logical; pictures are being shared in the moment, and our experience of the moment is by nature chronological. The film roll metaphor is seen here in the order of the pictures and the presentation, and it is finite (as is a physical film roll), not an endless and growing scroll. In fact, the number of pictures is intentionally kept finite through the automatic deletion, just as the space limitations of the actual film roll limits its number of pictures.

Still, when a picture is taken in order to be shared to one of these public and disappearing albums, the photo remains locally in the device's camera roll. When pictures are taken every day, for immediate sharing and other for motivations, last week's story pictures can become lost or fill up the endless camera roll. In this way, the growing and uncontrollable nature of this film roll metaphor can influence users to favour immediate sharing over reminiscence. Pictures closer to the top will be viewed more often and require less effort to browse than those that need to be scrolled to.

Just as there are examples of album metaphors in the past works reviewed above, there are also examples of this type of film roll. PhotoArcs [1] and the Picture Path [61] present moving paths of pictures, and 4Streams [93] presents different users' pictures in side-by-side synchronized slideshows. These are largely described as reminiscence-style viewing, but the format lets viewers connect quickly and briefly with the photographer on a finite ordered view, just as Stories do.

**The finite, ephemeral Story is a meaningful and more accurate application of a film roll metaphor.** An analog parallel (since looking at an actual film roll is not feasible) might be a series of connected polaroid snaps or a photobooth strip. Taking a moment now to share what we are experiencing now, one hour ago, and several hours ago, thereby creating and maintaining social connections online that could be shared in person without photography.

This use of the film roll metaphor was not the norm until after digital pictures was widely adopted, as seen in the continuing variety of research. It is unlikely that this immediate sharing use was predicted or was an intentional aspect of the film roll metaphor. Instead, it seems to have emerged as the task-artifact cycle continued with the new metaphor [17] and retrieved the social connection from in-person shared experience [56], bringing that into the digital and distance-separated space. So, a misapplied metaphor can have emerging benefits, but in this case, those benefits have been at the expense of excluding traditional practices: supporting new possibilities without the long-standing requirements.

Again, understanding the purpose of this metaphor within the larger process is key, but also understanding the reasoning for the design choice. If one potential metaphor is going to be so far-reaching that there is not room for other metaphorical aspects of the same process to have meaningful impact, the metaphor is not serving the design or the users, and the iterative changes of the task-artifact cycle will likely move further away from the already excluded areas of use. The variety of the research history is a clue to the variety in use and the need for careful consideration of what will support the intended aspects of use without suppressing others.

#### 6.4 Considering Picture Use(s)

These two ways of sharing of digital pictures, immediate connection and delayed reminiscence, are not in conflict with each other and both are limited by endlessly scrolling camera rolls. Picture storage is not a passive database. Pictures are interacted with within their storage (unlike files in file systems), and this storage is a living archive more than a static cloud backup. This needs a combination of database and narrative. An endless forced order scroll distances us from our own pictures, reminding us that we are disconnected from the collection and perpetually behind on the work of organizing. Across the history of digital picture research, this has been a common and consistent motivation: how to manage the potentially infinite growth of personal collections when the limit of the physical film roll and album are removed in the digital media. Over time, this has also been seen in the increased use of targeted search tasks in research, rather than browse or reminisce. In an endless scroll, a targeted search for one picture is far more achievable than a browse of thousands.

We see here the power of this digital metaphor to influence use [70]. As the only way to interact with our pictures is through this overwhelming reminder of the growing unmanaged and unmanageable history of pictures, fewer people

take on that work and more of our pictures are lost. One common design response to this is machine-generated memories or albums, which are placed on top of the existing metaphor and misses the opportunity for intentional design thought around its intent: how it might inform access to memories rather than lead it [80]. These give us access to a selected subset of our pasts, but only a fraction of it and only what is determined by various algorithms to choose what should be desirable to us.

As new possibilities and ideas emerge, designers must consider the broader use and origins of a design and not just its current state. The memory prompts of digital picture designs are being driven by the metaphor and are working around its limitations, in contradiction to the broad range of work on metaphor that emphasize metaphor as a tool to inform a design or otherwise act as part of a larger whole [70,80]. This does not change the underdeveloped and misplaced metaphor that causes the loss of access. It simply, occasionally, avoids it.

### 6.5 The Impact of Metaphor

Photography is a form of technology that has been part of family life, in one way or another, for nearly two centuries. That technology has not ceased to evolve for that entire duration and shows no signs of stopping soon [74]. With each change to the technologies of cameras and picture development there are new opportunities for how we interact with our pictures in a very long-lasting example of the task-artifact cycle. The move from primarily physical storage and interaction to digital is a large one, but it is not the only such shift in the history of photography. The introduction of the physical roll of film was another such major shift in what was possible.

Perhaps because of these many major shifts in use over two centuries, photography is a common example when discussing new media. Manovich discusses the modular nature of new media (a digital picture made of pixels) [54]. The modularity of digital picture collections, many individual pictures brought together as a whole, is distinct from a collection of physical pictures. Physical pictures together are limited by the practicalities of space, and interactions with them emphasize the individuality of each physical picture. Digitally, the individual picture can easily be lost in the large film roll of all pictures together with little interaction distinguishing one from the whole. The prevalence of the film roll across aspects of picture use, as revealed by our perspective-based inspection, shows this modularity of picture collections as it requires endless scrolling through the many as a whole in order to identify to access any individual picture. In this way the endless scroll of digital pictures blurs pictures together making them just as hard to see as they were on an unrolled strip of film.

When taking a broader view of metaphor within design, there is a lot to be learned from domestic photography. As new tasks have been introduced, old ones have been pushed aside. The film roll is a pervasive metaphor across digital photography, but a subtle one. It is rarely labeled as such, but it is present in nearly every method of accessing digital pictures. From our historical perspective, we show that this metaphor is likely an adaptation of existing digital file systems onto picture interactions. The film roll was not selected as a meaningful part of domestic photography. Instead, it was perhaps selected as the aspect of the analog process that most closely matched the file and folder metaphor of digital storage. Because of the existing digital ubiquity of file storage systems, the film roll spread across picture interactions instead of the variety of alternatives highlighted across the research history.

When a metaphor is that broad reaching, in any setting, it must be well understood within the larger needs and expectations of users. How metaphor is applied within media and digital settings is a broadly researched area, as well as the impacts of digital metaphors and the cycles entangled with their use. The film roll as a metaphor does not support the pre-existing tasks of picture activities. It has been seen to retrieve immediate sharing, within the Laws of the Media [56], but it also obsolesces central aspects of picture activities that are still actively sought out. The impact of this

misplaced metaphor is a lack of connection to our pictures and general discontent with the futility of managing the growing collections that have been a known problem since the earliest digital pictures interactions research.

The history of HCI in this area has shown that digital picture interactions are not lacking for research and that alternatives to the film roll are available. Yet the available interactions do not reflect that. We call on designers to look back on this history, to explore the motivations and questions from the past two decades of researchers, and then to build on that knowledge to create metaphors that better inform the different aspects of digital picture interactions.

Across the field, designers should question these sorts of metaphors that are seemingly the default but lack a design understanding of what it is doing for the users and for the tools. An underdeveloped metaphor can then be compared to the relevant history. The historical perspective allows for an investigation of shifting motivations and trends that can outline what changes over time and what differs between research and actual available use. This pairing of research history and current reality supports the intentional development of design metaphors that reflect and inform a complete picture of use.

## 7 CONCLUSION

We reflect on the history of digital picture interactions through a detailed review of past research proposing new designs and contrasted with a perspective-based inspection of the film roll metaphor throughout modern designs using the PhotoUse framework. Combined, these demonstrate that the metaphor is underdeveloped: pulled from its practical place in the analog picture process and spread throughout the digital equivalent with the necessary finiteness removed. This misuse leads to limited social reminiscence in digital tools. Further, we are able to identify the likely source of this metaphor as a simple adaptation of pre-existing digital file systems. More importantly, it is largely responsible for the lack of motivation to manage and engage with the growing collections of pictures most people have today and that has been motivating research to propose new designs for decades.

Through this work, we show how researchers should investigate the history of HCI as part of the continuing work of designing and especially when users have so consistently identified something missing. Looking back at past designs, we show that the film roll metaphor is not needed as broadly. This endless film roll, as our sole access to pictures, actively increases the work needed to maintain picture collections. Novel social pictures interactions resulting from new digital spaces, such as immediate and often ephemeral sharing, have done so around the finite film roll metaphor and now present a meaningful use of that. This can, and must, exist alongside social reminiscence, which draws on our past to bring meaning to ourselves, our families, and our communities. This reminiscence has long been supported by physical albums and we point to past research with digital pictures as the source of what should be a modern digital album interaction. This ties our pictures back to both the long history of domestic photography and the much shorter research history of digital interactions, while pushing ahead with the immediacy of sharing. Albums and film continue to have their roles to play, and we must include both for domestic photography and our social connections with it to continue.

## ACKNOWLEDGMENTS

The authors wish to acknowledge the sacred lands on which the University of Toronto operates. These lands are the traditional territories of the Huron-Wendat and Petun First Nations, the Seneca, the Haudenosaunee, and most recently, the Mississaugas of the Credit River. Today, the meeting place of Tkaronto is still the home to many Indigenous people from across Turtle Island, and we are grateful to have the opportunity to work in the community, on this territory.

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## A LONG TEXT DESCRIPTION OF FIGURE 2

A vertical timeline shows each of the years 1999 to 2019, from top to bottom. Blue lines on the timeline represent works included in the works reviewed in Section 4 with lines to the left indicating use of the film roll metaphor and lines to the right, not. Longer orange lines to the left indicate the investigations of digital picture use reviewed in Section 3. The names of each work are written at the outer end of each line. In 1999, there are two works: FotoFile (right) and Combs et al (right). In 2000, there are three works: Balabanović et al (left), PhotoFinder (right), and ShoeBox (left). In 2001, there are two works: PhotoMesa (left) and Wenyin et al (right). In 2002, an orange line is labeled Photoware, followed by four works: SmartAlbum (right), Personal Digi. Historian (left), Graham et al (left), and MyPhotos (left). 2003 has one work: PhotoTOC (left). In 2004, there are two works: MediaBrowser (left) and GIA (right). In 2005, there are two works: TimeQuilt (left) and MyLifeBits (left). In 2006, an orange line is labeled Photowork, followed by four works: PhotoArcs (left), iTell (right), Cherish (right), and SharePic (right). In 2007, there are four works: PhotoHelix (left), Living-Room (right), Memento (right), and Camelis (right). In 2008, there are seven works: Speculative designs (right), Flux (left), PhotoSIM (right), Pixaura (right), Zurfer (right), Flutter (right), and Souvenirs (right). In 2009, there are three works: Taylor & Cheverst (right), StoryBank (right), Orii et al (left). In 2010, an orange line is labeled Easy on that trigger, followed by three works: PhotoMagnets (left), Girgensohn et al (left), and 4Photos (right). 2011 has one work: Jesus et al (right). In 2012, there are two works: Ott et al (left) and MultiMediaNarratives (right). 2013 has one work: Piper et al (right). 2014 has one work: Pearl (right). In 2015, there are two works: 4Streams (left) and Jónsson et al (right). 2016 has



no works. In 2017, an orange line is labeled PhotoUse, followed by three works: Broekhuijsen et al (right), Frame of Mind (right), and Two-Sided (right). 2018 has one work: Tojo et al (right). In 2019, an orange line is labeled Back to real pictures, followed by two works: Chronoscope (left) and Zurn et al (left).

To the far right, the timeline is grouped into four sections with curled braces, each labeled with the title of a subsection of section 4. The first brace is labeled 4.1 Early Explorations and includes the years 1999 to 2002. The second is labeled 4.2 Rising Use, New Digital Tools and includes the years 2002 to 2008. The third is labeled 4.3 Common Desktop Use and includes the years 2008 to 2010. The fourth is labeled 4.4 Settled Design Standards and includes the years 2010 to 2019.

## B DEFINITION OF ACTIVITIES OF THE PHOTOUSE MODEL

Reproduced from [12]

### Accumulating

- Capturing: taking pictures; on-device quality triage to determine retaking the picture
- Collecting: adding pictures to your collection, which you did not capture yourself

### Curating

- Organising: tagging, moving, categorising, naming, captioning, archiving, and deleting
- Triaging: assessing, selecting for a specific purpose (e.g. sharing, decorating, and presenting)
- Managing: filing, backup, downloading, and uploading
- Editing: retouching, cropping, combining, correcting, and changing

### Retrieving

- Browsing: for example, browsing (casual viewing of pictures while interacting with them)
- Viewing: passive viewing of slideshows
- Searching: for example, goal-directed retrieving, searching

### Appropriating

- Sharing: remote sharing (online, on social media, or sending postcards), collocated sharing
- Printing: printing photos, a poster, or family albums
- Collaging: making a collage from (printed) photos, making (digital) booklets
- Tinkering: tinkering with printed photos, cutting and pasting printed photos

## C VERSIONS OF APPS INCLUDED IN THE PERSPECTIVE-BASED INSPECTION

Table C. Dates of access and app version numbers for all websites and mobile apps included in the perspective-based inspection.

Tool	Date of Web / Mobile Access (OS)	Version of Mobile App (OS)
Instagram*	28 April 2021	184.0 (Apple)
Facebook	4 May 2021 (Apple)	316.0 (Apple)
SnapChat*	28 April 2021	11.25.0.29 (Apple)
Apple iCloud / Apple Photos App	4 May 2021 (Apple)	iOS 14.5 (Apple)
Google Photos	7 May 2021 (Windows)	5.40.0.370514262 (Android)

Microsoft OneDrive+	5 May 2021 (Apple)	
DropBox	28 April 2021 (Apple)	232.2 (Apple)
Flickr+	4 May 2021 (Apple)	

\*Assessed on mobile app only  
 +Assessed on web only

**D DIGITAL FILM ROLL METAPHOR CODE BOOK**

**Categories:**

Scroll: How are pictures displayed in a scroll and how is that scroll limited  
 Order: What determines the order of pictures on a scroll  
 Order Control: How can the order of a scroll be controlled (if at all)

**Scroll:**

Endless: The scroll is (functionally) endless. Adding pictures is largely not controlled by the user  
 Grid: The scroll uses a grid view, for example showing rows of 3 pics at a time  
 Timeline: The scroll display time markers that quantify the scrolling  
 Slideshow: The scroll is a one-at-a-time display

**Order:**

Chronological: Chronologically ordered  
 Algorithm: Ordered by an unknown algorithm to optimize use as determined by the tool  
 Name: Filename ordered

**Order Control:**

Hard: App controls ordering, no user control  
 Default, editable: App controls initial ordering which can be reordered manually by a user  
 Custom: Order is fully user controlled

**Other:**

Access via film roll: an element that has no film roll metaphor, but functionally cannot be accessed without interacting with a film roll (e.g., editing a picture)  
 Timed Delete: pictures will be auto-deleted after some time without user input

**E EXAMPLES OF IDENTIFIED AREAS ENABLING ACTIVITIES ACROSS ALL TOOLS**

Table E. Examples of areas of included tools enabling various PhotoUse activities. A blank cell means that activity, as defined by [12], cannot be completed in that tool.

	Instagram	Facebook	SnapChat	Apple iCloud	Google Photos	OneDrive	DropBox	Flickr
Capturing	Take pictures within app						Take pictures within app	
Collecting	Add to “saved” collection			Download from shared albums				Add to “starred” posts

Triaging	Select pictures and add to a Story			Select pictures and add to an album			
Organizing	Tag friends in a picture or post			Tag people, correct auto-tagged people	Tag people (in shared albums)	Delete picture	Tag people
Editing	Add stickers to a picture			Draw on a picture			Rotate picture
Managing	Posts auto saved to camera roll	Save to camera roll		Upload pictures			
Browsing	Scroll through feed			Scroll through camera roll	Scroll through album/folder		
Viewing	View Story slideshow			View slideshow of album/folder			
Searching	Search by tag	Search all posts	Search by tag	Search by metadata	Search by file name	Search by tag	Search by metadata
Sharing	Send picture in private message			Create shared album/share existing album			
Printing					Order photobook		Order photobook
Tinkering			Cut picture to make a sticker				
Collaging	Create collection of pictures		Put one cut picture on another	Create collage			