“Slurp” Revisited: Using ‘system re-presencing’ to look back on, encounter, and design with the history of spatial interactivity and locative media

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Hand-based gestural interaction in augmented reality (AR) is an increasingly popular mechanism for spatial interactions. However, it presents many challenges. For example, most hand gesture interactions work well for interactions with virtual content and interfaces, but seldom work with physical devices and users' environment. To explore this, and rather than inventing new paradigms for AR interactions, this paper revisits Zigelbaum, Kumpf, Vazquez, and Ishii's 2008 project ‘Slurp’ [72] - a physical eyedropper to interact with digital content from IoT devices. We revive this historical work in a new modality of AR through a five step process: re-presecencing, design experimentation, scenario making, expansion through generative engagements with designers, and reflection. For the designers we engaged, looking back and designing with a restored prototype helped increased understanding of interactive strategies, intentions and rationales of original work. By revisiting Slurp, we also found many new potentials of its metaphorical interactions that could be applied in the context of emerging spatial computing platforms (*e.g.*, smart home devices). In doing so, we discuss the value of mining past works in new domains and demonstrate a new way of thinking about designing interactions in emerging platforms.

CCS Concepts: • **Human-centered computing → User centered design**; **Interaction design process and methods**; *Gestural input*; Mixed / augmented reality.

Additional Key Words and Phrases: historical precedents, software reconstruction, system re-presencing, augmented reality, gestural interface, metaphor, affordances, spatial interaction

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1 INTRODUCTION

A considerable amount has changed in the decade since Slurp [72] — a tangible eyedropper for moving content between devices (see Fig. 1) — was originally introduced as a new interactive approach for locative media - or the process of associating digital content with a physical, embodied artifact located in space. The enabling technologies for indoor positioning have significantly advanced [50, 66] and a slew of technical platforms for developing locative media have become readily available. This has made locative media more accessible to developers. Meanwhile, ubiquitous computing — in the form of smart home devices such as Google Home and Philips Hue Lights — has been widely adopted by

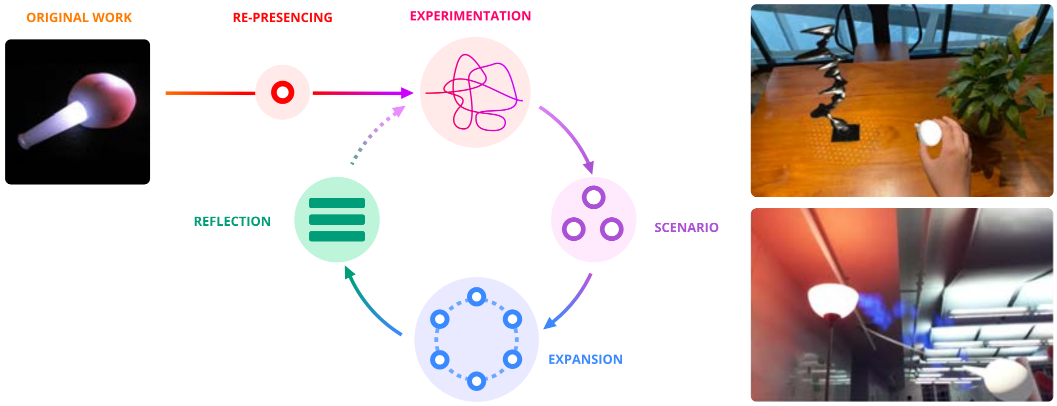


Fig. 1. Overview of our design process and artifacts. By revisiting "Slurp", we develop "SlurpAR" through a *system re-presencing* approach. Drawing from *software reconstruction*, it operates as an (iterative) sequence of *experimentation, scenario making, expansion, and reflection*. We detail this method in Section4. The dotted line between reflection and experimentation indicates the possibility for iteration.

consumers. These consequential changes in these conditions (technology, maturity, affordability, and genuine ubiquity) enable new potentials for their original vision.

Simultaneously, there has been a rise in the availability and affordability of new complementary technologies for locative media. This includes augmented reality (AR), for example, which has seen increasing interest of late. This has been spurred by the availability of more affordable gestural technologies, such as the Leap Motion, as well as, integrated consumer-focused headsets like HoloLens and Magic Leap One. Equally, the access to augmented reality experiences on modern smartphones have made such experiences commonplace in everyday scenarios.

Despite increasing popularity, many challenges remain. A recent survey of cross-device interactions remains complex both in technical orchestration and in the interaction between devices [8]. Specifically, in being able to manipulate and interact with content in these scenarios, Brudy *et al.* [8] note the wide array of approaches to designing interactions that exist in the field, most of which rely on direct interaction with interactive surfaces or mid-air hand-based gestures. As such, gestural interactions in AR are usually designed for arm-reach distance interaction only, and create challenges for content located beyond the body [58]. Additionally, hand-based gestural interactions often prioritize interaction with virtual content (*e.g.*, a virtual button, or 3D models), but rarely support richer interactions and intersections between the physical environment or the devices and objects it contains. Finally, as an augmented environment becomes more complex, in the number of cross-device interactions supported and/or the number of content manipulations and interactions that can be performed, gesture-based controls become cumbersome and require additional forms of feedback and support. In this, metaphors and naive physics help conceptually align aspects of the real and virtual worlds, thereby offering a potent strategy to better communicate interaction strategies to users [6, 33, 36, 70]. To address these challenges in light of recent interest in AR, a large array of new gesture-based and metaphorical approaches for augmented reality have been presented of late [23, 51, 56, 63]. We, instead, suggest that solutions to these challenges may already exist and that close examination and experimentation with historical precedents may offer valuable strategies for designing interactions for emerging platforms.

Within the context of AR interactions, we are inspired by the 2008 project "Slurp" [72] and consider how its successes with metaphorical approaches for locative media might inform contemporary gesture-based design paradigms. We do this as a process of *system re-presencing*. This term draws from media archeology where it is used in reference to restoration and preservation of interactive media, for example games. Re-presencing acknowledges exact historical replicas or representations are challenging or unrealistic to achieve and leaves room for interpretation while being reverent to the conditions – material, functional, and experiential – of the original work. Within our work, re-presencing consists of remaking a historical interactive system so that it can be encountered and experienced by a designer, and with that tactic experiential knowledge re-interpreted, adapted and applied to new platforms, mediums and interactive scenarios. Drawing inspiration from recent efforts in *software reconstruction* to restore, revive and critically examine past works [41, 49], we outline an iterative research-through-design [73] process that begins with a close study of the original precedent and re-presencing of the experience with contemporary technologies. The original project employed a tangible device that appropriates the appearance and affordances of an eyedropper in combination with a series of IR sensors placed on physical objects to augment them for interaction. This allowed for a metaphorically-informed transfer of digital information between the augmented objects and eyedropper devices. We describe our exploration of re-presencing Slurp as an interface for locative media in AR and reflect on this process of revisiting and reviving a decade old project in the context of new technical toolkits and platforms for locative media.

In this paper, we reflect on *system re-presencing*, and more generally *software reconstruction*, as a potential tool for research-through-design. We examine how looking back and working with historical precedents as a design methodology that can help to re-contextualize prior work through their revival, reconstruction, and re-presencing in other modalities of interaction. Our work contributes to the DIS and HCI community with the discussion of iterative, reflective process that adapts, extends, and applies *software reconstruction* to tangible, immersive, and embodied computing. We offer a case study and discussion of this process and our work to revive the Slurp project using an AR and gestural interface, and reflections on the design implications of reviving and re-examining past works. Additionally, we discuss how the process of re-presencing itself enables a deeper engagement with the sensorial experience of original Slurp project and the limitations of reviving works based on textual descriptions from conference papers. Once revived, we engage experts in co-design workshops to examine the prototype and speculate on new opportunities for locative media. Through this, we highlight the productive distinction between familiarity with and direct encounters with past strategies. We also illustrate how this can inform design practice by offering designers the ability to experiment with and pursue alternative directions that might not have been available at the time of the original work. Findings offer qualitative insights of the benefits, limitations, and potential impacts of our design methodology and process, as well as future directions for this methodology in design research and practice.

2 RELATED WORK

Our work is inspired by prior art in software reconstruction, locative media, metaphorical interactions, and affordances.

2.1 Software Reconstruction and Past, Present, and Future Prototypes

Research in ubiquitous computing often places an anticipatory lens on its work, prioritizing technology artefacts concerned with futures. For example, Odom *et al.* [47] remark that prototypes, the subject of most research investigations, are an "instantiation of a future outcome." Bell and Dourish [4] strongly critique ubicomp for its fascination with "proximate futures" that "places its achievements out of reach, while simultaneously blinding us to current practice". However, this "concern with potential future computational worlds" has become a resource for design futures. For example, Blythe suggests the imaginary abstract as a mechanism to present, plausible, but fictional future studies for critique and discourse [7]. There has also been a rise in speculative- design-led technology inquiry [14, 15, 22, 38, 43, 44, 69]. While there may be retrospectives and surveys of the domain, this rarely engages the literal objects that are the focus of our fields work: the systems, software, and devices we inquire upon.

We are not alone in this recognition. Recent efforts call attention to the value of historical perspectives. Soden et al. "the lack of historical view threatens to leave out a wealth of resources that can inspire design, provide exemplars for comparative analysis, and help develop a deeper understanding of technology development.[59]." Barzdell, Barzdell, and Hansen highlight how the artefacts produced by design and design research embody knowledge in distinct and important ways that scholarship alone cannot represent [1]. Yet, there are many practices and fields that place great value on the preserving and restoring the historical technical artefact so that encounters with the history, cultures, and knowledge they encode can happen. These offer potential resources for design and HCI. Work in game studies offers an instructive example. Paola Antonelli's efforts to add video games to MOMAs collection is perhaps the most notable (and controversial) [40]. It also reflects the many challenges of restoring and preserving interactive works: inputs, controllers, displays, and other underlying technologies change over time or may not be available [31, 60]. Similarly, Hodges illustrates both the importance of and plethora of considerations in restoring just the haptic experience of a game [31]. Others note the commitment to "the original experience" can create tensions and impossibilities, especially if an exact replica of the original system or software is the intended outcome. Swalwell [60] notes such an approach may additionally "hamper more critical thinking about games history, preservation and presentation". In contrast, media archeology takes a more flexible position; it serves to both preserve and interpret works by "re-presencing" them [32]. This is reverent to the conditions – material, functional, and experiential – of the original without being hamstrung by them.

In this vein, we highlight two recent projects. The first by Pangaro and McLeish [49] and the second by Cardoso Llach and Donaldson [41]. Pangaro & McLeish [49] replicate Gordon Pask's Colloquy of Mobiles – a significant artefact in the history of cybernetics – to celebrate its 50_{th} anniversary in 2018. Using Pask's original documentation, they developed a full-scale replica that was faithful to the original work and its interactions. The technology, however, reflected that available in 2018. By using updated technology, the original cybernetic approaches are juxtaposed with, and can be critically examined in light of, modern AI such as voice interfaces. Cardoso Llach and Donaldson [41] propose software reconstruction as a method of experimental prototyping that draws from media archaeological and historical reconstruction practices. They note, like Swalwell and Pangaro, that this process is not intended to replicate the original hardware or software but is about "approximating the experience of using these technologies by enacting their fundamental logic and their key visual, gestural, and ergonomic signatures." They demonstrate this by reconstructing two seminal works of computer aided design (Steven A. Coons' "Coons Patch" and Ivan Sutherland's "Sketchpad"). These efforts offer both a methodology and a value for adapting, re-interpreting, and experimenting with historical precedents through modern technology. They inspire our approach.

2.2 Locative media

This work is centered around the examination of "locative media" [67]. Locative media can be broadly defined as the range of technologies involved in enabling location-aware media experiences. This includes work across the domains of cultural heritage [2], crowd-sourced tourism [21], games and entertainment [13], urban exploration [17, 24], new media arts [61], information management [55, 72], and cross-device systems [8]. Early work is grounded in the advent of GPS-enabled smartphones and initially on large-scale outdoor urban experiences [5]. Later, it began to capitalize and incorporate other relevant technologies, including indoor positioning, tangible interfaces, augmented reality toolkits and cross-device interactions [5, 67]. Recently, Geollery [17, 18] presents an interactively reconstructed mirrored world with geo-tagged social media and street views[1]. As it did, locative media created new scenarios and opportunities to interact with context- and location- aware content within indoor environments. For instance, project "Pick-and-drop" [55] explored a creative way using a pen to manipulate digital content between multiple computer displays. Ec(h)o explores playful approaches to indoor museum interactive soundscapes by incorporating tangible interfaces [64]. Slurp explored the movement of digital content between augmented physical objects in a smart office scenario [72]. Wilken and Goggins assert these early explorations of locative media as "a harbinger of the emergent media of our time," such as the Internet of things [67].

More recently projects have continued this line of inquiry. For example, Reality Editor [29, 30] – an augmented reality spatial interface for linking and programming smart objects - or Deus EM Machina [71] – an electromagnetic emissions-based approach to localizing smart objects and providing contextually relevant controls through a mobile interface – can be seen as natural continuations of locative media in the context of the 'smart home'.

2.3 Metaphorical Interactions and Affordances

Complex systems and digital interactions often rely on metaphors as a way to communicate affordances [11, 26], as they are an effective means for "understanding and experiencing one kind of thing in terms of another. " [39] They signal potential operations and visualize activities with the computer in a way that is familiar and recognizable to users [42]. Metaphors are typically used to signal the affordances for interaction. Affordances, as originally proposed by Gibson [11], offered an ecological approach to visual perception of real environments. This was adopted by Norman [45, 46] to inform the design of objects, and later by the field of HCI to inform the design of digital interfaces. Affordance refers to perceived or actual properties of an object that determine how it could be possibly used [48]. Signaling interactive affordances within computer interfaces can reduce people's cognitive load, as well as, error rates [65], although simply mimicking physical affordances in digital interactions may be insufficient to create fully intuitive interactions [11]. The canonical example is the "desktop metaphor", a concept that endures in contemporary interface design. Metaphors and the affordances they signal remain effective means of communicating and understanding complex and abstract processes in computing interfaces today and continue to shape the way we interact with digital devices. Metaphors are widely used in both screen-based and other forms of computing, for example, tangible user interfaces [34, 35]. Ishii's Tangible Media Group is known for a wide range of experiments that use metaphors to embody abstract digital information or actions into physical interfaces, *e.g.*, [34, 35, 57]. This includes the design of Slurp [72], the focus of this work. Another metaphorical example is the I/O Brush [57], which uses a tangible paint brush with an embedded camera. The affordances of the tangible brush in combination with a strong metaphorical analog encourages people to pick up the attributes (color, texture) of everyday objects to create expressive digital drawings.

Equally, as augmented reality often relies on abstract digital interaction and the performance of gesture-based content manipulations, metaphors have become a major component of AR interfaces [6, 33, 36]. Much recent work concentrates on the fidelity and accuracy of mid-air gestures, the guessability of hand-gesture in AR [54, 68], and use an elicitation approach [51, 63] to identify user's preferred hand-gesture and increase understanding of users' mental models. For example, using this, Pham *et al.* [51] explore how common gestures are adopted, used and performed across a range of scales and interactions with virtual content. Henderson and Feiner proposed "opportunistic controls" - that uses

[1]Geollery: https://www.geollery.com

the natural affordances of existing tangible objects to facilitate intuitive and improved gestures and interactions in AR [28]. Ro *et al.* enable a smartphone to act as a metaphorical projector to control augmented projections based on how it is positioned and oriented by a user [56]. While most work focuses on proximal interactions with reachable content through mid-air gestures, some exploration of strategies and affordances for far-distance interactions has been conducted. For example, Feuchtner and Müller present a novel metaphorical technique of visually stretching a user's arm through AR to enable interact with objects that are normally beyond arm's reach [23] while AR developer Lee Vermeulen created a playful metaphorical approach to control smart lights by shooting them with a bow and arrow in AR [62]. We similarly explore metaphorical interfaces and the affordances for simultaneous near- and far- distances interactions in AR as part of this work.

3 REVISITING SLURP

Zigelbaum *et al.* [72] designed "Slurp" in 2008 as an exploration of locative media, the affordances of a tangible interface in information transfer, and as a novel metaphorical interface. As shown in Fig. 2, this exploration yielded a tangible eyedropper consisting of an RGB LED for feedback, a force-sensitive resistor to detect applied pressure, and vibrotactile feedback. It communicates with a series of IR-enabled nodes that are attached to objects within the environment, thereby allowing it to act as an intermediary between the eyedropper and a physical object or device in the environment. Multiple nodes are deployed in space and the eyedropper can be used to extract and store media from one node at a time, and then send (or inject) that media to another device, for example, transferring a file from one computer to another.

The approach is grounded in a conceptual metaphor that relates slurping liquid as an analog for data transfer. They say: "one approach is to treat abstract digital media as water. Water, like some digital objects, is difficult to manipulate with bare hands. We can splash it around, but we need specialized tools to perform precise operations with it. [72, p. 2568]".

(a) Slurp extracting a digital object from a sculpture (b) Slurp injecting a digital object onto a screen

Fig. 2. The original "Slurp" project [72] created by Zigelbaum, Kumpf, Vazquez, and Ishii at MIT Media Lab.

"Slurp" offers an alternative, creative solution for spatial interactions with locative media, but it has a few limitations. First, it relies on an additional tangible device, which creates barriers to deploying it in practice. The number of augmented objects constrains the potential for interaction with and transfer between aspects of the physical environment. Second, it uses infrared communications so it requires proximal the eyedropper and node to be relatively proximal and within line-of-sight; limiting the potential for distant interactions. Third, it only offers limited visual feedback on what information has been transferred to the eyedropper via an RGB LED. These are acknowledged by the authors. This included feedback from qualitative demonstrations that questioned the need for a "separate device just for accessing digital information from physical object", as well as how such an approach might be scaled [72]. We base our efforts on the technical description of this work as presented in 2008, as well as the original authors’ evaluation of the limitations and future directions for their interactive strategy.

4 METHODOLOGY: FROM SOFTWARE RECONSTRUCTION TO SYSTEM REPRESENCING

In SlurpAR, we revive this historical metaphorical interface and re-examine it in the context of new toolkits for spatial media, namely augmented reality, gestural interfaces, and smart home systems.

This effort was situated within a larger one-year research project to consider the affordances of metaphorical interfaces in augmented reality. Slurp was highlighted as a relevant precedent based on its metaphorical approach. Slurp afforded near and far spatial interactions with multimodal digital content and between heterogeneous devices (from screens to speakers). This aligned with many of the motivations of the project. Additionally, Slurp was selected because it was relatively overlooked by the field. It was presented at an early edition of alt.chi (a track that invites thought-provoking and boundary pushing work), the approach remained largely overlooked by research explorations of metaphorical and tangible interactions, garnering just 44 citations in eleven years. For comparison, Coelho, Ishii, & Maes’s Surflex [12] presented as a work-in-progress at CHI the same year has 104 citations while earlier from the Tangible Media Group demonstrating tangible interactive devices [9, 10, 53] each have several hundred citations. We felt this made it an interesting case to revive and re-examine.

In discussing their augmented eyedropper, the original authors situate the power of their approach, and more broadly tangible and embodied interfaces, as one rooted in the combination of metaphor, affordance, and interaction in physical space. They also equally note the problems: “tangibles don’t scale well, and although capable of manipulating abstract data the use of indirect mappings reduces the benefit of physicalization [72, p 2566].” Further, they note that it requires adding motes to each object you want to interact with. They document this as an obstacle for adoption: “one user wasn’t sure why someone would want a separate device just for accessing digital information [72, p 2572].” Owing to this, the original authors admit that their approach can be “less practical” [72, p 2572]. This question of scalability remained unresolved in their work. We sought to engage it as part of our explorations.

Drawing inspiration from recent efforts in software reconstruction [41], we adapted this approach to a critical examination of contemporary interaction strategies through the lens of historical precedents. We examine software reconstruction as a framework for research-through-design where deep engagement with, re-interpretation of, and experiments with historical precedents reveal perspectives on and new affordances for interaction with present technologies. It is important to note that we do not intend “reconstruction” to be interpreted as an exact replica. We adopt media archeology’s more liberal view of having a reverence to the condition of the original but without being restricted by it. The intention is to re-presence the interactive system and its experience such that its strategies, intentions, and contexts can be interpreted and critically examined. Hence, we suggest the term “system representing” may be preferable to “software reconstruction” in this circumstance to both acknowledge the shifts in modalities and implementation, as well as, the nature of the precedent project not being limited simply to ’software’ alone.

Our work translates Slurp from a tangible to an augmented reality interface for locative media. It does this for several reasons. First, this offers a means to address unanswered questions in the scalability of the approach. Second,

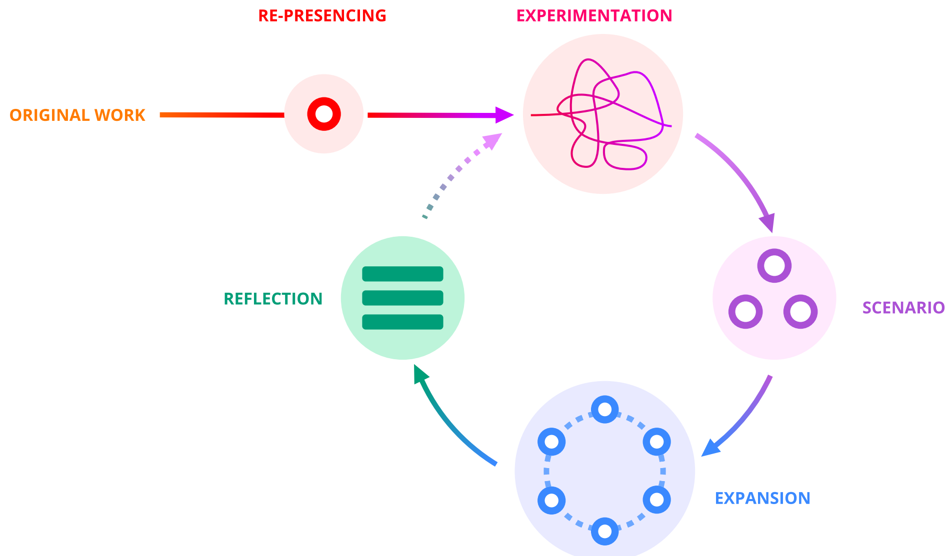


Fig. 3. Overview of our system re-presencing approach. Beginning by revisiting and studying the original work, the process begins by *re-presencing* - a revival and restoration of the interactive experience. It then operates as an (iterative) sequence of *experimentation, scenario making, expansion, and reflection*. The dotted line between reflection and experimentation indicates the possibility for iteration.

we attempted to restore and adapt the interactions and experience of the original metaphorical approach so it did not require a tangible device and motes. Third, AR additionally allowed for a rapid means to revive the metaphorical approach and to experimentation with alternatives. Finally, in re-examining this precedent using AR, adapting it to this new medium of interactivity explores how the underlying the metaphorical interaction has relevance and new affordances for designing interactions today.

We next describe our process of re-presencing a historical interactive work and extending it to a new domain. In this case, we seek to give the original approach new relevance and applicability in the context of the burgeoning field of augmented reality. We organize this process as a sequence of five related activities - re-presencing, experimentation, scenario-making, expansion, and reflection - that are designed to foster a continued reflection on contemporary interaction strategies through the lens of antecedent technologies. Specifically, we add creative experimentation to enhance the affordances of the restored work, the design of new interaction scenarios to re-contextualize the original project in contemporary scenarios, and speculation and reflection with design experts, as extensions to prior efforts in software reconstruction.

(1) **Re-presencing**: We revive the historical approach using present toolkits and approaches. In this case, we analyzed and adapted Slurp to work within commercially available toolkits for augmented reality. In this phase, we focus on a restoration of the experience of interaction; but are not necessarily concerned with an exact replica of the original technology.
(2) **Experimentation**: This phase recognizes that computational capabilities have significantly advanced since the original incarnation. With a functional version restored and adapted to contemporary toolkits, we critically examine the original aspirations of the project in light of the advanced features and functionality that are now

possible. Through iterative experimentation, these opportunities are enacted and the original implementation progressed.

(3) **Scenarios**: An interactive scenario is prepared so that the restored software can be experienced broadly. This is an opportunity for continued dialog around the effort and the possibilities it affords.

(4) **Expansion**: As part of this dialog, we engage experts with the restored system and its interactive experience. We invited these designers to productively expand on our scenarios within a generative workshop.

(5) **Reflection**: Finally, the designers are invited to reflect on prevailing practices, reconsider present interactive strategies, and suggest valuable alternatives through an engaged encounter with antecedent approaches.

Importantly, the latter part of the process is not intended as an empirical exercise in assessing the interactive strategies prepared through this process, nor are the expert perspectives offered as evidence. Instead, this paper contributes a case study of an alternative design practice: one that values the past, the direct encounters with the design knowledge these interactive experiences expresses, and showcases the value of mining historical precedents in informing present and future strategies. The approach is ultimately intended to suggest the value of 'looking back' on and designing with direct encounters with historical works as an underappreciated methodology in human-computer interaction as much recent work notes the field's prioritization of proximal futures over present realities in prototyping interactive experiences [4, 47, 55].

4.1 Re-presencing

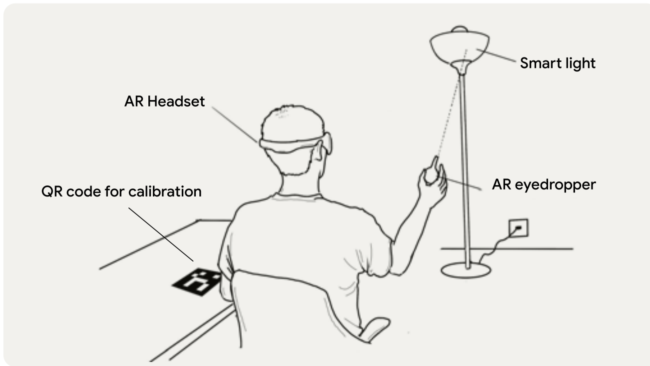
In this section, we outline our approach to "restoring" Slurp both technically and conceptually. This effort began with a rigorous review of the original project. This included mapping the affordances and interactions from a tangible tool into an augmented virtual tool, SlurpAR. Through iterative prototyping, the original work was re-presenced and adapted to work within augmented reality.

As illustrated in Fig. 4, we used an Oculus Rift[2] and a Zed Mini camera[3] with a pass-through AR solution for prototyping. For hand-tracking, a Leap Motion device[4] was attached beneath the Zed Mini camera to get accurate data of hand-gestures. Prototypes were developed in Unity with C#. A 3D model of an eyedropper was created and was designed to be placed between the middle of the index finger and the thumb.

4.1.1 Remediating "tangibility". The original design emphasizes the tangibility of the eyedropper. By transitioning from a tangible to a virtual, augmented eyedropper, we must acknowledge the loss of physicality and implicit tactile feedback. As a key aspect of the original work, this was an important factor for us to consider in the restoration process. We aimed to compensate, in part, for this by using the hand itself as an "opportunistic control" [28].

Instead of using a FSR sensor as in the original or another tangible input, to initiate a slurping gesture, our approach calculates the distance between the thumb and index finger. As the two fingers get close to one another, the system detects a pinch gesture and triggers the slurp action to either draw in or release content, dependent on the state of the eyedropper. The pinch gesture offers several advantages. First, it aligns metaphorically with a physical eyedropper and with users' existing mental models of the interaction. Second, it is relatively easy and accurate for a hand-gesture tracking system (*e.g.* Leap Motion) to recognize this action. It does so robustly and reliably across a broad range of positions and orientations of the hand. Finally and most importantly, when performing the pinch gesture to trigger the

[2]Oculus Rift: https://www.oculus.com/rift
[3]Zed Mini camera: https://www.stereolabs.com/zed-mini
[4]Leap Motion: https://www.ultraleap.com/product/leap-motion-controller



(a) SlurpAR setup for smart lights

(b) Headset setup

Fig. 4. (a) Locative media setup for the smart lights, used an AR marker to align the virtual environment with the actual physical environment, so that we can detect if the user is pointing at a specific light. (b) We attached a Leap Motion sensor for gestural tracking and a Zed Mini Camera to turn the Oculus Rift VR headset into an AR pass-through headset.

virtual Slurp, contact between the thumb and index finger generates implicit and intuitive haptic feedback. This helps to embody and reinforce the virtual action. We must acknowledge our virtual AR eyedropper approach does not offer the same rich tangible qualities as found in the original Slurp.

4.2 Experimentation

With an initial version restored, we attended to the constraints and limitations of the original project as well as the opportunities for enhanced interactivity that the medium of AR afforded. Specifically, we examined three potential enhancements, namely: improved visual feedback; interaction with new forms of locative media; and enabling interaction with the environment beyond installed 'nodes'.

4.2.1 Augmented visual feedback. Within the original enactment, Slurp used visual and vibrotactile feedback to allow a user to explore the environment for digital objects. They likened this interaction to "the beeping of a metal detector or the sounds from a Geiger counter to indicate the presence of objects invisible to the user." Changes and animation of color in the eyedropper reinforce target selection and extraction of content from the environment into the tangible device and provide continuous feedback on the state of Slurp.

We recognized that identifying locative media targets and selecting them could be better supported in AR and experimented with alternative visual indicators. The first trial was a small circular cursor, and it can be raycast with the physical environment, staying on top of the detected surface. The second iteration added a straight line from the eyedropper to the target position. The third, and final iteration, uses a Bezier curve to mimic physics of attraction, which can bend towards a target position, like a fishing pole (see Fig 4). The curve, by snapping to and locking on targets, affords richer visual feedback while exploring the environment. It is also helpful in visualizing actions performed. Moreover, is useful to visualize the feedback of the user's actions. In the original, "Slurp's stem illuminates and mirrors the color of the target object in the same way that the stem of an eyedropper takes on the color of the liquid it is placed in [72]." We use the curve to further reinforce this action and the metaphor of slurping. We introduce a colored participle effect along the curve as the user is slurping in or out content from virtual eyedropper. This further embodies

Fig. 5. A curved line mimics a fishing pole to indicate the slurping target and communicate a sense of locking.

the abstract process with the the curved Bezier adding additional interactive feedback to increase the discoverability of interactive devices.

4.2.2 New forms of locative media. The original project notes that "as computers become more pervasive through the physical world, the spatial relationships between computational devices gain importance." The original implementation relied on augmented nodes being placed on physical and digital objects around the environment. This included screens, digital cameras and sculptures. Since the original Slurp, new categories of devices that can support locative media have become commonplace. This includes smart home devices like lightbulbs and voice assistants. This affords new opportunities for locative media that can be situated in and moved between aspects of a user's physical environment. Additionally, augmented reality offers other advantages over the original implementation; namely, the potential for more flexible approaches to annotating the environment. Rather than using physical nodes, we instead create a virtual model of the environment that organizes the locative media targets.

To interact with screens, physical objects, and devices, such as smart lighting, we created a virtual room in Unity. This organizes virtual targets within a three-dimensional layout that correspond to things within the real physical environment. Using OpenCV, an AR marker was used to calibrate and align the virtual with the real environment. Using this approach, when the user points the AR eyedropper at a smart lightbulb, it can easily recognize and target which device they are pointing at. We note that there are many approaches to aligning real and digital environments for locative media. Other strategies for indoor localization (*e.g.*, [50, 66]) as well as computer visions could achieve similar outcomes, augment this strategy or even automate the virtual model. Regardless, we note that a virtual model allows for greater flexibility than the node-based strategies of the original, Slurp, and greater extensibility to new forms of smart objects and locative media.

4.2.3 Interaction between the virtual and physical environment. Augmented reality affords new interactions between virtual and physical content that the original Slurp could not support. For example, we experimented with the virtual eyedropper as a mechanism to pick-up, place, and manipulate virtual content (3D models and video players) in users' physical environments. We used Zed Mini's simultaneous localization and mapping (SLAM) technology to procedurally

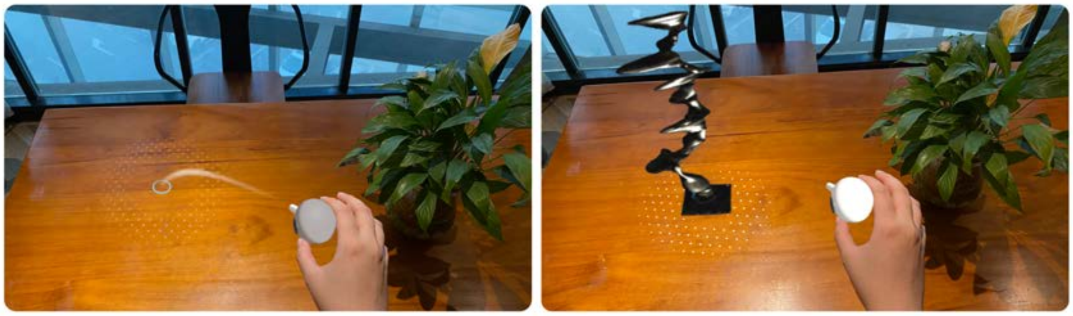


Fig. 6. Placing and manipulating a 3D model with an AR eyedropper in physical environments.

generate 3D meshes of the environment and its surfaces including walls, tables, and the ground. This allowed us to detect surfaces, ray-cast from the eyedropper, and place the content on top of the selected point in the environment. This is depicted in Figure 6.

In addition, we recognized that AR and the video capture it relies on affords other extensions over the original Slurp application. Computer vision enables object recognition, and color feature extraction to be performed in the physical environment. This creates opportunities for real-time interactions with the environment that the node-based pre-configured infrastructure of the original Slurp could not support. This is next illustrated by and discussed in our constructed scenario.

4.2.4 Observations. Through restoration and re-presencing in AR, we demonstrate how many of the original critiques and limitations of earlier approaches no longer apply. Slurp's metaphorical approach is open to a wider array of interactions by virtue of the affordances of today's locative technologies, frameworks like SLAM, and the networked nature of smart home devices. Through our experiments, we highlight broader set of interactions with physical objects, smart devices or the environment that AR and locative media is extensible to without reliance on motes.

4.3 Scenario

Much as Slurp's creators augmented their lab space, to iterate, test, and experiment with the SlurpAR platform we augmented our design studio. In the original Slurp, they later constructed a demonstrator in the context of the smart office. This recognized the challenge of "how to move and share data objects" across digital whiteboards, shared displays, audio systems, tablets, phones, and laptops. This was used to informally present and qualitatively evaluate the approach.

An open house at the design studio provided opportunistic way for us to conduct a similar informal presentation and evaluation of the SlurpAR approach. During the open house, 20 people informally encountered, explored, and discussed the prototype orchestrated as an interactive scenario – in this case of a smart home augmented with locative media – to enable participation with and conversation around the affordances of our approach and its extensions over the original precedent. The scenario was constructed around a desktop computer, a Google Home voice assistant, and Philips Hue smart light bulbs. The screen of the desktop computer allowed digital files, 3D models, and other content to be extracted/injected with the AR eyedropper.

In addition, the scenario explored how the virtual eyedropper could interact with abstract environmental information and smart devices. As an eyedropper is often used as a metaphor for a color-picker in many computer-aid design tools (*e.g.*, Photoshop), we re-engaged the underlying metaphor and enabled SlurpAR to pick up color from the physical environment. We extract the color at the pointer location from the Zed Mini camera’s video feed. The color data can further be applied to any smart light by pointing at it and performing the pinch gesture. The color data is transferred through the local network to the target device. This is illustrated in Fig. 7.

Fig. 7. (a) By using the AR gestural eyedropper to pick up color from real-world environment, the body of the eyedropper changes color based on the extracted color. (b) The emitted color is animated as particles to visualize and represent the intangible process.

The AR eyedropper communicates its status during color selection activities by changing the color of its body. A plain white body indicates an empty status, while a colored body conveys the latest color that has been extracted from the environment (see Fig. 7 and Fig. 8). As cross-device interactions can be conceptually abstract, we also apply an animated particle effect along the bezier selection curve as a color is being slurped in or out of the environment (see Fig. 8.) This helps to reveal and materialize this intangible action, to intuitively communicate the relationship between gesture and action, and to reinforce the metaphorical process of color data being transferred between the environment and devices.

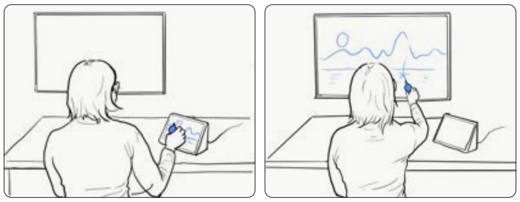
As noted above, 20 visitors to the lab interacted with this scenario. The approach was much as in the original paper. Demonstrations of the working prototype and interactive scenario were provided and first-person use of the system was encouraged. Participants who tried the interactive scenario firsthand were each instrumented with the Zed Mini-enabled headset and had the opportunity to experiment with several interactive smart home devices through SlurpAR. Most visitors tried the demonstrator for a few minutes. They all found the experience intuitive, and the metaphor of the eyedropper easy to grasp. They often remarked on the playful and enjoyable experience. The animation effect was found by most people who used the system to be “magical” and many remarked that it “reinforced the metaphorical process”. While this is incorporated, to a degree, in the original Slurp, AR allows the abstract and invisible flow of information between the environment and our metaphorical eyedropper to be richly represented. We found this also allowed people to more directly perceive the actions taking place and form a stronger conceptual understanding of the process. Much as in the original paper, many visitors offered suggestions and critiques for improvements, additional scenarios, and alternative applications. For example, some mentioned the gesture recognizer failed to recognize their gestures when moving too fast or out of the field of view of the Leap Motion sensor due to the technology limitation. Many also mentioned arm fatigue after playing it for a while, which is a common challenge for in-air hand gesture interactions, so shorter interaction sessions would be more preferable. Additionally, a few visitors suggested slurping other content such as media and files, similarly to the original slurp.

Fig. 8. A sequence of slurping a color from the AR eyedropper to smart lights in the environment. A line from the eyedropper to the target increases the discoverability of the interactive devices. Particle streams indicate the transfer of information between the eyedropper and the target device.

4.4 Expansion and Reflection

In preparing this scenario, we did not replicate an identical repertoire of interactions that precisely correspond with the original project. Instead, we sought to honor the original intentions of the Slurp project while highlighting new adaptations and extensions to its support for locative media made possible through its restoration in augmented reality. While color picking is illustrative of one such possible extension over the original work, it is the tip of the iceberg. This interaction paradigm in AR could be expanded to more complex digital information, as well as a broader array of smart home devices and interactions with the physical environment. To explore this, we considered our interactive scenario as a discursive artefact to engage design professionals in AR in dialog with this re-presenced system and speculate on alternative directions for AR it inspires.

Owing to the COVID-19 pandemic, this work had to be conducted remotely and thus differs consequently from similar efforts [41]. Instead, we opted for co-design workshops as a vehicle for conversation and speculation through scenario-making. We recruited six domain experts (three female) through personal connections, email lists and social media. The workshops were conducted one-on-one with the research team through Google Meet and Zoom. Four of the participants were professional designers or UX engineers from technical companies with substantial experience of producing AR products and services; 2 of the participants were researchers from universities in the field of human-computer interaction. During the one-hour session with each participant, they were initially introduced to the original Slurp project, then introduced to our SlurpAR concept through a video that walked through the interactive scenario previously described. They were next invited to generate and discuss alternative scenarios. Some concepts closely aligned to the original Slurp suggesting subtle extensions that engage it with other now-common cross-device technologies, *e.g.*, AirDrop files between devices. Others spotted new potentials in the medium of AR to create unique cross-device interactions. For example, using the camera in the AR headset to recognize text from a book or magazine and allow it to be passed to a smart home speaker to read it out loud. Another example explored more prospective possibilities to sample objects from the digital world and inject them into augmented spaces like “Slurp a cloud from the sky and put it into my room as an AR cloud”. Concepts generated were collated across participants and analyzed using an iterative bottom up coding approach to identify emergent themes and ultimately aggregate the responses into related categories. This analysis focused on interaction themes and relationships between the interaction types found within the concepts. Generated concepts fell into five main locative-media interactions a) bringing attributes of the physical world into the digital world; b) bringing physical world humans and objects into digital world; c) transferring information between multiple digital devices; d) bringing information from digital devices to into physical environment; and e) using Slurp as a pointing and selection device (*e.g.*, mouse). Fig. 9 illustrates the designed interaction.



(a) Slurp videos from a smart home display to a smart TV for seamless video casting

(b) Slurp the text from a book to a smart speaker to read it out loud

(c) Select an area with slurp and hold to conduct a visual search of the area, using the AR Slurp as an analogy to mouse

(d) Slurp a cloud from the sky, and slurp it out into my room as an AR cloud

Fig. 9. Storyboards of the concepts generated in the co-design workshops

Through our experiments and workshops, we highlighted a broader set of interactions with physical objects, smart devices, or the environment that AR and locative media is extensible to: manipulating purely virtual content (slurping 3D models, and media players), controlling smart appliances, and interacting with the environment (extracting color). However, this was also an opportunity to reflect on the process of system re-presencing with expert designers.

The six participating experts (mentioned above) who engaged with our “looking back as a design method” process also took part in semi-structured interviews afterwards. This invited them to evaluate the benefits, potential impact, and limitations of our design process and methodology. Interviews were transcribed, and, as with the concepts, were iteratively coded using a bottom-up approach. Overall, most experts found the approach “interesting and exciting”. P2 noted that, “the process gives me a framework to think about the design concepts, starts from a prior work and theories, and discusses a few basic examples in a new context, and then expands to more visionary concepts, it helps me to expand the concept step by step.” In addition, P5 also saw the value of our design method, and thought “this should be a very inspiring methodology for the community to follow and replicate.” P2 drew comparison to generative design practices, remarking that our method was “a reverse of the traditional brainstorm process.” They also noted “[t]he traditional brainstorming is quite open, but this process starts from some existing examples and theories, then expands, it’s very directional and efficient.” Moreover, participants felt “looking back” on past work with a restored prototype facilitated *increased understanding of the original work*. Re-experiencing a working prototype was especially helpful to reveal the intentions and rationales behind the project. P4 remarked experiencing the prototype illustrated “the limitations, the thinkings behind it, and what are the future potentials” in ways that the scholarly text could not. Another participant described how this approach helped to “build a comprehensive narrative around [Slurp]”. Encountering the historical work as a working prototype and considering new applications and scenarios from the lens of present technologies “put the original work into a bigger context” and worked to “connect the dots of related ideas from the ‘Slurp’ project.”

This suggests our approach offers designers an enriching way to encounter historical precedents that can reveals its deeper contexts and inspire creative interpretation.

5 DISCUSSION - RE-PRESENCING AS A DESIGN METHODOLOGY

By re-presencing this more than a decade old project, we revisited the original Slurp Project in the context of IoT and augmented reality. Through this process, we reflect on how these methods create value, what can be learned and what opportunities this methodology – restoring, experiencing and designing with historical precedents – presents the field.

5.1 "Representing" in AR

Zigelbaum *et al.* [72, p 2573] critically reflect on their approach, stating: "Basing an interaction on existing physical models will always be problematic if the interface doesn't function exactly in the same way as its model. "

This engages a critique that could be made of our *reconstruction* and restoration: it does not operate exactly as the model. We have *re-presenced* a tangible interface with an intangible gestural approach. Further, the original Slurp places tangibility at its core. Is it correct to discard the tangible input? We recognize this is a contentious issue. It also one often and much discussed and debated in the realms of software preservation and archiving. We draw parallels Paola Antonelli's efforts to add video games to MOMAs collection is as a notable and controversial example of software reconstruction [40]. Here massively multiplayer games could not practically be exhibited so the experience of play was captured in video. Similarly, for older games, the screens, controllers or other materials were no longer available; so they were approximated. To quote, Zigelbaum *et al.* (albeit out of context) "in practical use design tradeoffs must be made".

While we are, however, reverent to the functional, experiential, and interactive conditions of the original, we must acknowledge the lack of physicality and materiality in our implementation as a potential limitation. The experience is no longer tangible and people will encounter it somewhat differently. This preempts a question of what is and what is not reconstruction in this context. For these reasons, "system re-presencing" is preferred for two reasons. It emphasizes a re-presencing and respect of the original work in the experience, interactions, and values it embodied. We also note the term is broader and inclusive of both hardware and software, as well as, paradigms in interactivity (tangible, gestural, embodied, etc.) Finally, the demands of realistic, exact historical representations are often unachievable and unrealistic: for example, the materials used in the form of Slurp are not specified, and the technical implementation is briefly and partially described. We instead view reconstruction as an interpretation; a process that prioritizes "closely looking at and, when possible, touching, operating, and performing the object of study [32]" as a means to discover, engage with, and reflect on the original work, rather than attempt to simply replicate it. This provides room for alternative enactments and creative experimentation.

Augmented reality as a medium for reconstruction has many merits. As we illustrate, AR is well-suited to re-presencing HCI's histories. It allows for rapid reconstruction, experimentation, and iteration of historical systems. Additionally, AR affords reconstructions to be shared for critical engagement in new contexts. As such, AR could be used to quickly revive, re-examine, and reflect on a large body of historical artefacts from HCI, across its many sub-domains of tangible, physical, embodied, ambient computing.

5.2 Defamiliarizing Technologies

Prior work by Cardoso Llach and Donaldson highlights software reconstruction an means to "unlearn the logic of present day CAD software" and through engagement with the restored technological artefacts to "prompting a reflection on the embodied experience of designing computationally both then and now [41]." We found this process to be similarly fruitful. For us as designers, restoring this work through a complimentary medium (in this case AR), prompted considerable reflection on the present approaches to gestural and spatial interactions embedded in AR interfaces. This process also helped unsettle the present narratives and interactive paradigms of IoT and AR by locating them more directly in the emergence and history of locative media. The engaged, hands-on process of reconstruction helped to defamiliarize present approaches. This was furthered by the embodied and sensorial experience of interacting the software artefacts throughout its restoration.

5.3 Presenting Alternatives

Defamiliarization isn't just a vehicle for critical reflection on design, but as Bell and Sengers [3] note it can be leveraged to inform design. Prior work in software reconstruction attempts to only restore and embody interactive works in present circumstances. We go beyond the process to complicate the historical precedent in present technologies. Our additional processes of experimentation, scenario-making and reflection is an extension to prior efforts.

This afforded interaction designers[5] to directly encounter design knowledge from the past. While designers often draw inspiration from prior work and approaches, there is a significant distinction between indirect familiarity and a direct encounter with past strategies. Within our work, this offered practical and productive opportunities for us to experiment with and pursue alternative directions that might not have been available at the time of the original work.

Equally, we see this as a complimentary strategy to many materially engaged, critical practices that seek to posit alternative presents [14, 48]. Specifically, we view this as a form of critical making and material speculation [65] wherein we explore and enact and historically-informed alternative presents as interactive technology artefacts. This process afforded us a materially-informed dialog space for continuous examination of historical and contemporary technology practice. We suggest this process as a complementary approach to emerging design-led methods for speculating on alternatives and one that emphasizes technological artifacts as containers of knowledge [1, 37, 52, 65]. The interactivity also affords a rich way for audiences and experts to be involved with these alternatives. We found they could be posited as a plausibly 'new' experience of technology and afford a discursive space that reflected the entanglements between historical and contemporary approaches to interaction.

5.4 Reflecting on Histories

As noted previously, Wilken and Goggins view locative media as "a harbinger of the emergent media of our time [67]" and draws a line between these early geolocative technologies and the Internet of Things. We subtly attend to this legacy in changes of context in the demonstrator scenarios: the smart office grounds the original Slurp, while the smart home is emphasized in SlurpAR. This reflects not only the change in the domain over time but also change in values. In some ways, these two scenarios reflect their times. As Harrison, Tatar and Sengers [27] suggest, the original Slurp may reflect an emphasis of HCI's 2nd paradigm – interaction as information communication – whereas our revival and the experiments prepared concern the gestural, expressive and phenomenologically-informed interaction: they reflect HCI's broader shift from tasks and productivity to more playful experiences situated in a broader world of interactivity. However, the term 'locative media' itself has dwindled in these contexts. Research efforts surrounding embodied, tangible and ubiquitous computing in the past five years is rarely labeled with this phrase (with exception of mobile storytelling and cultural heritage applications); however the term 'cross-device interaction' is prevalent and has

[5]We as a research team of interaction designers and design researchers had the opportunity to directly engage the re-presenced experience, however, and as our workshops took place on video conferencing our participants had limited engagement with the interactive artifact. We acknowledge that further work is needed to explore the potential of encountering re-presenced design artifacts.

emerged in its place. As Cardoso Llach and Donaldson remark, these many observations on expert language, encoded values, and other dimensions surfaced through software reconstruction complement and "adds nuance to our reading of the historical texts."

Similarly, system re-presencing offers a comparative technique to examine our changing relationship to technology. The preparation of a revived interface – both for designer and audience – encourages us to consider the broader context of this historical precedents and reflect on what has changed from then to now. When the original Slurp was published, computing was significantly different: computing was expensive, touch-screens were not widely available, mobile phones were bulky and not nearly as functional as they are today, and smart and internet connected appliances were not available to consumers. Shifting demonstrator scenarios from the office to home subtly attends to how computing has shaped everyday life in a decade. While we have not fully engaged this opportunity as part of this work, we highlight the potential of system re-presencing as means to investigate our increasing entanglements with technology [25], by juxtaposing them against the conditions and context of historical works. We also believe this may be a helpful approach to growing critical and reflective design practices [16].

6 LIMITATIONS

This paper offers a case study of an alternative design practice that mines historical precedents to inform present interaction strategies. Some limitations must be acknowledged. Due to COVID-19, the engagement with experts was truncated and in a format that did not allow for ideal sensorial engagements. Our described process follows a more linear flow yet as our diagram suggests (see Fig. 3) it affords iterative cycles of re-presencing, experimentation, scenario making and reflection. Other critiques might include that the original Slurp was untested in a formal setting, and our reconstruction is similarly untested in formal settings. We highlight that this paper is not intended as an empirical exercise but also acknowledge that this has some implications on our rationales for choosing to reconstruct Slurp. Not every historical precedent may be useful to revisit, but we do not offer general guidance how or why to choose historic examples. This is deliberate, as we recognize that propositions for and values in historical reconstruction may be varied: to support archiving, education, inspiration, innovation, and/or critical studies. While it might be beneficial, we feel explicit direction or criteria for selection may instead work to narrow scopes and agendas of future inquiry. Finally, we illustrate how an examination of a single work is rich, but recognize that this may be a limited perspective on the histories and cultures of socio-technical systems and interactive strategies. Reviving multiple related works in tandem may draw more complete lines. We suggest this as an excellent opportunity for future inquiry.

7 FUTURE (PAST) WORK

The methodology of reviving a historical precedent in new context and modality holds a interesting direction for future design research activities. In preparing this project, we were limited in the ways we could engage designers and researchers in dialog with the scenarios and experiences prepared. In future iterations of this work, we hope to explore other, more public, formats to facilitate broader engagement, dialog, and speculation between (expert) audiences and reconstructed software. We also imagine our scenario could be further expanded to enable the historical precedent to be in deeper exchange with technological presents. Technologies such as computer vision techniques [20] and low-cost indoor localization techniques [50, 66] could provide opportunities for future experimentation and scenario-making for opportunistic interfaces [19], locative-media, and cross-device interactions. There are also likely to be many more overlooked historical precedents in the fields of tangible interaction and ubicomp that could be re-examined. Future work might revive a series of projects from a specific conference or from a research lab to critically examine their histories, experiences, and affordances in contemporary technology contexts.

8 CONCLUSION

In this paper, we re-examine and re-presence a historical precedent in a new modality of AR. We do this to consider the history and development of locative media, as well as, critically examine new potentials of its underlying metaphorical approach in the context of contemporary spatial computing and interactive tangible devices (*e.g.*, smart home devices). The intent of this effort is not to validate SlurpAR's efficacy compared to other existing approaches, but in creative engagement with the process of reconstruction and restoration, we are also able to identify new possibilities and values. By engaging current platforms, SlurpAR overcomes some constraints of original, addressing the issues of discoverability, cost, perceptive feedback, and support of both near-and-far interaction. In our generative workshop, augmented reality design professionals engaged with and speculated upon interactions between the physical environment and digital world. This generated both design directions and offered opportunity for reflection on the process itself: how re-presencing allows for a deeper engagement with and sensorial experience of historical software artefacts. Our phased design process for system re-presencing is described and we encourage other designers to adapt and extend this method. We believe looking back through software reconstruction is a useful design research methodology to re-examine the history and affordances of many past tangible, augmented, and embodied interactions.

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