Emulation Practices in Place:

Coordinating Software Preservation in Libraries, Archives, and Museums

Report from 2019 Summer Fieldwork

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For more information, visit the project website
https://www.softwarepreservationnetwork.org/fcop/.

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Statement on use

Data analysis is underway and these early results are preliminary. For these reasons, the current document should be considered as an interim report and not the final summation of findings. Because Acker's findings are currently under scholarly peer review, we ask that you not distribute, publicly comment, cite or publish this document until after January 1, 2021.

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Introduction

This report presents early results from field research work from the Fostering Communities of Practice: Software Preservation and Emulation in Libraries, Archives and Museums project (hereafter "FCoP"), a research initiative led by Principal Investigators (PIs) Jessica Meyerson and Zach Vowell, supported by the Institute for Museum and Library Services, and implemented in collaboration with three cohort partner teams from the project [1]. In year 2 of the project, Amelia Acker from University of Texas (the author of this report) was selected to participate in the project by researching teams in action as they implemented emulation in their software preservation programs. The report comprises an overview, motivations, research activities and findings from Dr. Amelia Acker as the team researcher. The initial FCoP project began in 2018, Acker joined in January 2019, and began doing field research in June 2019.

There is a robust research literature on digital preservation of information objects in cultural heritage institutions [2], [3], but software preservation supported with emulation techniques is still relatively new to library and information science [4]. Indeed, most emulation literature from the last two decades has tended to focus on best practices for format migration, digital storage, description of materials for access, or the testing and evaluation of specific tools [5]. But despite the research literature, emulation practices across the world and amongst many different organizations exist. In fact, some emulation efforts and their connection software curation project are gaining momentum with broader educational and community building efforts such as the Council on Library and Information Resource's software and data curation post-doctoral fellowship programs, the National Digital stewardship Residency Program, and the Software Preservation Network community efforts [1], [6], [7].

Emulation practices are well-known amongst die-hard video game fans, music producers, research data managers, and preservation practitioners who care for and access software-dependent information. Even so, emulation as a category of information practice is largely unknown to the broader research communities concerned with information systems that support access, research infrastructures, and preserving knowledge through time. Moreover, there is little empirical research that has examined the coordination, decomposition of tasks, or the work of implementing preservation and access programs that information professionals undertake in situ. While many human computer interaction (HCI), computer supportive collaborative work (CSCW), and science and technology (STS) scholars have examined the coordination of work practices of obsolete software and software development [8]–[10], few have considered software emulation as a category of service provision and collections access that libraries, archives, and museums (LAMs) increasingly provide as part of their unique cultural heritage missions.

The FCoP project aims to address these gaps in knowledge about emulation practices in information institutions in two ways. First by creating a cohort of teams from LAM institutions implementing emulation services into their service provision portfolios and second, by gathering empirical evidence about these teams' workflows, approaches, and existing software

preservation programs. The overall project aims to facilitate communities with experience and research gathered about emulation practices in place—from workflows to developing best practices, to circulating knowledge from case studies. The overall results of FCoP activities will create new knowledge about the current state of emulation programs in libraries, museums, and archives in the United States.

Process and Scope

The findings from this study should be understood as exploratory research—the first critical step in a multiphase research program investigating digital preservation, data persistence, and software emulation practices in support of archival access, exhibition experiences, and primary source research for software collections and software-dependent materials. As is appropriate in exploratory work, we are focused on discovery instead of evaluation or testing.

The goal of this field work was to gather empirical evidence, synthesize observations, and propose conceptual frameworks that will support the development of software preservation strategies and the provision of emulation services in libraries, archives, and museums that support software curation. As the visiting researcher, I did not conduct reviews of existing services, nor did I evaluate participants in their ongoing work, planning, or ongoing organizational responsibilities in this study. Thus, none of these findings should be considered evaluative. Instead these findings should be viewed as emergent, ongoing, and open. We would also like to emphasize that the names and job positions of participants are not specifically identified in this report but that cohort team leads who are identified as “site champions” in field dispatches can be easily identified based on their participation in broader, public FCoP initiatives.

As a grant-funded initiative, FCoP project’s starting point was to build a community of expertise through engagement and support using an emulation platform for individual case studies at each site. That is, each of the cohort members had institutional access to the emulation-as-a-service infrastructure (EAASI) platform [11]. Instead of focusing on each users’ experience of a singular tool or computing environment, I present observations from the ongoing processes and team workflows for implementing emulation services for communities of practice. The project conceived all cohort members as co-researchers as well as participants in the research. As the lead researcher, I adopted a holistic approach to the data collected, framing the approach around participatory workflow analysis of emulation practices. Participatory workflow analysis involves bringing together stakeholders to document and reflect upon their workflow patterns [12]. Using interview techniques, including activity diagrams and data flow diagramming, workflow patterns are described, documented, and connected to organizational tasks accomplished in teams [13]–[15].

As we discovered over the course of this project, there are multiple perspectives on emulation practices. These multiple perspectives prevent a singular or homogenous lens for each site, workflow, or case study, even if all sites use the same emulation platform mentioned above. Instead, the overall findings and recommendations from this report focus on data from three participating cohort sites’ knowledge about the practices of software emulation and the

encounters with emulation they support, their views on coordinating workflows of emulation; and finally, communication about emulation to users, organizational teams, and stakeholders. As well, findings are presented with special regard to the unique case studies and institutional mandates at each site (respectively, a technology museum and two university research libraries). At the end of this report, I present some preliminary themes and recommendations based on concepts, models, and competencies that should guide the implementation and provision of emulation services in cultural heritage organizations.

Audience for this Report

This report is presented with three intended groups of readers.

First, it is addressed to those who manage institutions—administrators, team leads, and directors who typically manage teams and operations that provide information services. Those who are responsible for managing service provision, identifying technology needs and planning new initiatives, delegating staff time and expertise, and allocating support for successful collections access will benefit from these findings.

This work is also intended for **information professionals currently involved in implementing or planning preservation programs** with software-dependent materials or software in their collections. Even if software curation is beyond your current institutional capacity, providing meaningful access to these materials will necessarily involve plans, workflows, and policies related to emulation practices.

Finally, resource allocators can read this report to learn more about emulation practices that benefit a variety of stakeholders, especially organizations concerned with access to digital information. From program officers at public research agencies to directors from philanthropic organizations, **funders addressing capacity building in digital cultural preservation and technology access initiatives** will benefit from these early insights in their visioning and ongoing granting efforts for America's information institutions.

Research Activities

In Spring of 2018, Acker joined the FCoP project as an independent researcher and gained access to cohort sites to answer the following research questions over the summer of 2019. This section describes the motivations, research questions, theoretical framework, methods and project design of the summer fieldwork for observing teams at three field sites. It ends by describing the data collection process at each site and the data sources used to support the findings and recommendations. Before presenting recommendations, I survey the last year of research activities, present findings from each of the three sites, and then present preliminary themes found across all sites.

Research Questions

The research questions were designed to examine 'emulation practices in place' and expand the study of software development, digital preservation, and computer supported cooperative work. Emulation methods are deployed when a computing environment is "required to access older generation digital objects is re-created on a modern computer, allowing legacy software to run inside an emulation layer on current systems" [4]. There are many technical, legal, and social challenges to implementing emulation methods, including access to software, original operating systems, and securing ownership rights [16]. There is an urgent need to develop comprehensive resources that describe existing approaches and known preservation standards specific to software-dependent collections and software emulation in US cultural heritage organizations. This includes a conception of long-term access to digital cultural memory and a general vocabulary for understanding digital preservation from software development and software emulation perspectives. The project was guided by the following research questions. In this report, I focus on answering questions 1 and 3 with preliminary data collected in the field.

1. How are software preservation practices applied in different stewardship contexts and cultural heritage organizations? How are administration and technical workflows, preservation standards, and metadata documentation developed and deployed across different work sites?

2. How are initial, representative, or proof of concept software or operating systems appraised and selected for emulation?

3. How do the unique environs of a cultural heritage organization impact the selection, standards, and workflows for digital preservation, particularly with regard to theories and applications of software emulation?

Theoretical framework

Theoretical frameworks are generated from concepts, expectations, and theories that inform your research and guide data collection and analysis. For this research, I drew from STS and infrastructure studies perspectives that see software preservation as a collaborative work process between different sets of actors, technologies, and standards [17]. Understanding software preservation as a collaborative process, allows us to examine emulation through workflows amongst small groups of experts in larger organizations. Since software emulation is a collaborative effort in organizations that support complex social interactions with people, and things, and people's things from the past being made present, we need a deep understanding of how people and groups work together in support of accomplishing tasks together through workflows [9], [18], [19].

For most STS and infrastructure studies scholars, as well as CSCW researchers, examining administrative and technical workflows means studying the processes of work in place [20], arrangements of people and technology, and then their practices [21] in the everyday—for example working with a particular emulation tool or particular kinds of software and hardware as part of an individual's daily with a team of other information professionals in a library or museum.

Digital work, such as preserving software-dependent artifacts, is often hidden, obfuscated or abstracted, so transparency and accountability are benefits from this perspective. In addition to using software, the maintenance work involved in preservation infrastructures is typically hidden, not documented, or not well known in hierarchical organizations such as universities or academic libraries [22]. Thus, documenting complex processes like software preservation increase accountability for those involved in digital labor of maintenance and coordination but can be essential to the design and transformation of future and current systems because we can support, intervene, iterate these processes in more effective and transparent ways.

Studying work processes in organizations as complex social interactions and then depicting them embedded in place are important for accurately capturing the many layers of social and technical interactions in the adoption of new technology and practices of work [23]. It also reveals how infrastructure is made up of humans [24] in their experiential knowledge and efforts coordinating and maintaining systems. This theoretical framework also emphasizes understanding the articulation and coordination amongst teams or members in an organization [25], because articulating existing or ongoing processes helps people know what they are doing as part of working complex systems, such as an information organization responsible for providing software preservation services. Finally, empirical observations about workflow processes like emulation practices also enables transparency and accountability of those processes once they have become formalized in place [26].

Methodology

In creating a collaborative research design, I worked with FCoP PIs and cohort team leads at three sites to observe each site for 3 full working days and to interview each available team member for 1 hour. In addition to each site's FCoP cohort team members, I interviewed other employees that collaborate, support, manage, or work in relation to each of the teams in their preservation work. This included archivists, catalogers, public services staff, metadata librarians, systems administrators, software developers, and administrators, amongst other titles. While brief, embedding for three days at each site, combined with one-on-one interviews resulted in over 50 hours of rich, interview data and hundreds of pages of field notes. My collaborators (hereafter, "site champions") planned for me to observe team meetings, visit exhibits, and access documents that teams have used to document their software curation projects. Typically, the site champions were the people that I will spent the most time with—shadowing them as they move through their day and observing their work because of their status as a team leader and connection to the project.

In spring of 2019, I received IRB approval from UT's Office of Research Support and Compliance which reviews and approves all research with human subjects. This research involved observing people in their workplaces and recording interviews, so I developed a verbal consent protocol that would assure confidentiality and privacy of participants. With verbal consent protocols, researchers are able to ensure consent from participants without creating records of their names or workplaces. This allows participants to participate in interviews anonymously, while the researcher can maintain confidentiality and privacy of participants' identities and roles in their organizations.

Data collection and sources

For interviews, I used the participatory workflow analysis method of inquiry. It asks participants to map out or draw their workflows, or describe them step-by-step by decomposing a specific task [12]. By asking participants about each step in their workflow and developing diagrams to structure our conversations, I was able to observe parts of these flow diagrams at each site. Following on interviews, I followed participants around and observed their work with emulation, metadata development, and software preservation processes. Below are the different sources of data gathered during fieldwork in Summer 2019.

1. **Participatory observation notes** from labs, exhibition spaces, team meetings, offices and research areas of each site. I observed team meetings at all three sites for approximately 5 hours. I visited and spent time in exhibition spaces at all three sites for approximately 6 hours.
2. Notes and some audio recordings from **interviews** with FCoP team members, staff members, engineers, developers, interns and managers for a total of 25 interviews (52% Female, 48% Male) for approximately 31 hours. Interviews typically lasted from 30 minutes to 1 hour, with the shortest being 18 minutes and the longest being 2 hours and 2 minutes. I used participatory workflow analysis to guide my interview protocol with

team members. The method gives context to workflows, organizational responsibilities, and illustrates task coordination amongst teams that work in large or mid-sized organizations.

3. In addition to individual interviews, I spent approximately 18 hours (or two half days) shadowing site champions and observing their work.
4. **Photographs** of signage, physical environment, work stations, exhibits, software resources, collections, access records, and local environs.
5. Short **videos and screencasts** of workflows at desks, work stations, and of interviewees describing tasks.
6. Copies of **documentation** that supported preservation workflows and team coordination: manuals, calendar timelines, descriptions of activities, whiteboard sketching, slide decks, and handouts.

In addition to interviews, observations, and field notes, I have also produced and analyzed transcripts from six 1-1 interviews and observation notes in the conduct of everyday meetings coordinating services, programming and preservation work. Parts of meeting notes were subject to analysis, wherein I took note of actors' accounts of their work when it was strictly relevant to their FCoP project participation. These data sources and documents will continue to be coded for themes and using grounded theory technique [27], and presented in future scholarly work prepared by the author. By combining macro-level community participation with micro-level analysis with these data sources and their synthesis, we are better able to characterize the kinds of order produced and maintained within each of the organizations using emulation practices with multiple use cases.

Findings: Observing Emulation in Place

Over 9 days and across three sites I interviewed individuals, observed meetings, visited exhibitions, and shadowed site champions while they carried out their everyday work. I used interview data, observational data, and experiences from each field site to synthesize observations, generate questions, and investigate practices of software emulation in place. Here I present three field dispatches from each site and then synthesis of major themes and principles found across each of the organizations. I close with some broad recommendations for future work on emulation programs, including community building and research planning initiatives.

Field dispatches

The following three field descriptions are lightly edited versions of public "field dispatches" published as blog posts on the FCoP project website [1].

Living Computers History Museum + Lab

The first site I visited was the Living Computers History Museum + Lab in Seattle, Washington. LCM+L is a computing technology museum that features an impressive collection of early working computers from the late twentieth century, including a super computer, several mainframes and minicomputers, and over thirty microcomputers. Many of these machines were donated Paul Allen, the co-founder of Microsoft and founder of the museum. Allen believed that direct access to technology can provide transformational experiences for young people, and each of these exhibition experiences showcase how working, vintage computers like mainframes and minicomputers led to mobile phones, the primary computing device for most people in the world.

For their FCoP cohort project, LCM+L is piloting a number of emulators for vintage operating systems and software in order to preserve and share what they call the "Middle Ages of Computing". The pilot is focused on best practices and workflow documentation for working with emulators, the EaaSI sandbox, and exploring the experience of emulators themselves. Some emulators that the museum uses are open source or already available to consumers, like the Floppy Emu Disk Emulator. But many of the emulators that LCM+L uses are developed in-house by a team of vintage computing engineers who maintain the museum's unique, comprehensive collection.

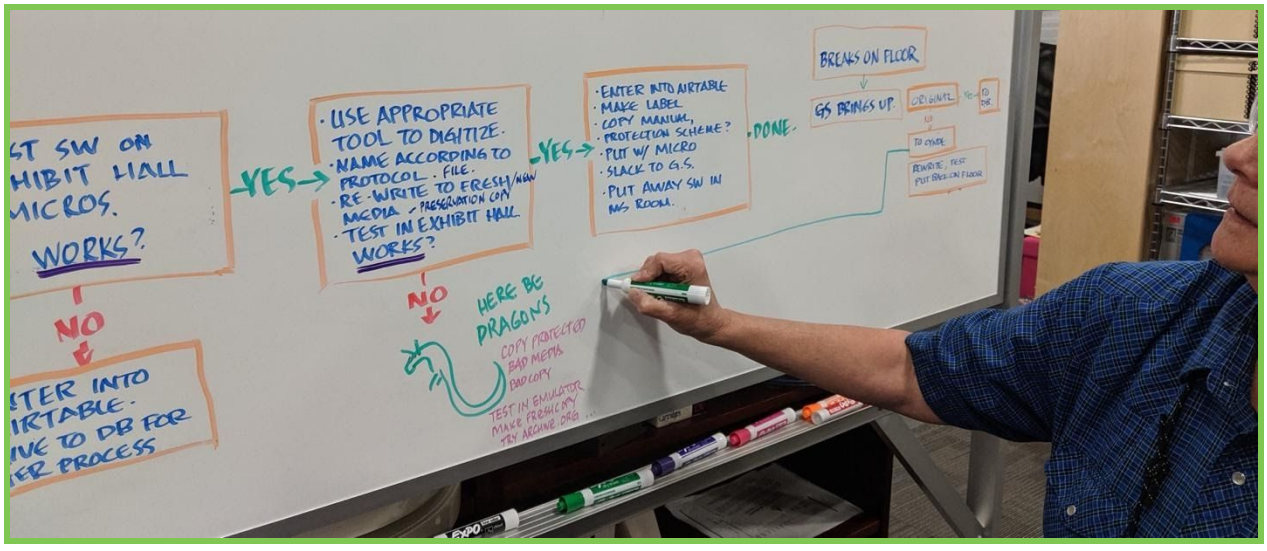
LCM+L is what is known as a "touch museum", meaning that visitors and researchers are encouraged to physically interact with the machines, their operating systems, and software, including physical media formats like floppy disks and game cartridges. At the heart of this mission is the goal of keeping of software, operating systems, and hardware alive with emulators. During my visit, I witnessed many groups of kids on field trips, as well as

individual visitors form the public, ranging from teens to older adults. Each had different approaches to the machines based on their personal computing experiences. For example, in an exhibit on mini-computers, a punch card machine with a hardware emulator for writing allows visitors to type and punch their own cards. While most of the kids were able to type and begin punching data to cards, only the older adult visitors knew how to remove punched cards from the machine.

Over three days, I worked closely with the museum's Collections Manager and Software Preservation Lab lead. My first "site champion" arranged for me to interview the members of the preservation and archives teams and other museum staff members, and provided me with behind the scenes access to observe this computing museum in action. During my field trip, I interviewed 8 participants for approximately 1 hour each, I attended one preservation services meeting with 5 organization members, and I observed the site champion across 5 emulation or software preservation case studies for approximately 7 hours.

Problem solving (aka "here be dragons")

One aim of analyzing workflows is to illustrate how work happens as a process. For software preservation workflows, I am particularly interested in how are problems discovered, how are preservation opportunities identified, and what are the steps involved ensuring access. In my interviews with LCM+L employees, I discovered that software preservation tasks typically presented themselves as problems or "mysteries" to be solved. Often language of discovery, revelation, detective work, and adventuring was used to describe these preservation problems that may be solved with emulation techniques, amongst many other possible strategies.



Decision tree workflow diagram featuring problems to overcome and possible outcomes.

Software preservation practice is a kind of problem solving process. Software preservation and emulation is no different—an archivist has to identify an access goal, a problem that can be overcome, plan a solution, and document the process as you solve each problem. So, on the first day, when I shadowed the Software Preservation Lab lead on a number of preservation tasks, we approached each one as an opportunity to document the process and to observe documentation resources that already existed.

On days two and three, I attended a preservation team meeting and interviewed archivists, engineers, and guest services guides from across the museum, interviewing them about their typical workdays, role responsibilities, and perceptions of emulation in support of the museum's overall mission and unique preservation mandate to keep computers alive. An overall goal for this cohort project is developing documentation that carefully describes preservation workflows, challenges, findings, and ongoing recommendations for the larger software preservation community. So, during my interviews and observations I was particularly interested in where and how documentation resulted, and how team members' workflows intersected, overlapped, where decision points happen.

Chains of Documentation

As the FCoP project researcher, our goal for gathering preservation workflows and describing procedural activities is not to recommend a complete a set of requirements, but instead to characterize unique software preservation environments in situ. By observing the variety of work supported by emulation we can better understand the different kinds of problems that preservationists confront in their work and how they go about solving them in teams.

Throughout my visit I was struck by the documentation chains that already existed as part of the LCHM+L's pilot and the metadata that was collected as I shadowed the site champion. We used all sorts of emulators to create disk images and preservation copies for the exhibit floor. I was especially excited to observe DECtape data transfers using a tape hardware emulator on a LAB-8/E part of the DEC PDP-8 family from the 1970s. The machine has a beautiful green color scheme, the tapes themselves are a very unique in blue casing, and the setup involved a daisy chain of three adapters to support data transfer.

Observing, documenting, and elaborating these processes can be seen as a kind of task decomposition that over the course of the FCoP project may result in some generalizable knowledge about how software preservation and emulation works in place.
Documentation chains created by different team members are leveraged often when solving problems in a methodical pacing of a series of steps in a decision tree that typically begins with the atomic level of where the bits are stored. The detective work in identifying the constraints, problems and possible outcomes was part of these extensive chains of documents that informed pacing, goal-setting, allocating staff time. On the other hand, some unique emulation challenges such as a rare microcomputer may have little

preservation documentation; and instead, the original manuals are paramount to creating a convincing emulator.

For most of the preservation case studies (or "mysteries") I observed shadowing my site champion began with use emulation techniques to make preservation copies for the museum collection and then for the exhibition floor as well. In a number of my interviews with preservation engineers, I learned of different bespoke emulation cases for singular machines appeared or were intended for the exhibit floors in the museums. These tailored emulators were typically commissioned to a particular machine in the collection and on display in the museum. Interestingly, while there were many machines emulated throughout the museum on display, only bespoke emulators created by staff members were described in placards and exhibit descriptions.

At this museum, there were two veins of emulation practices that have different genres of documentation. One kind, emulation for preservation was well documented with in-house manuals that outlined each step involved in accessing, copying, and preserving a bitstream (usually tape or disc media). Another kind of labor intensive practice tailored to unique items in the collection typically aimed at exhibiting a working machine involves what I call "emulation for exhibition" involves building emulators (typically for older hardware, microcomputers, or mini computers) so that collection objects can operate in exhibits. Bespoke emulation in the service of exhibition is less likely to be documented in an operating manual for preservationists, but instead documented by crediting the preservation engineer who created the software or the machine code.

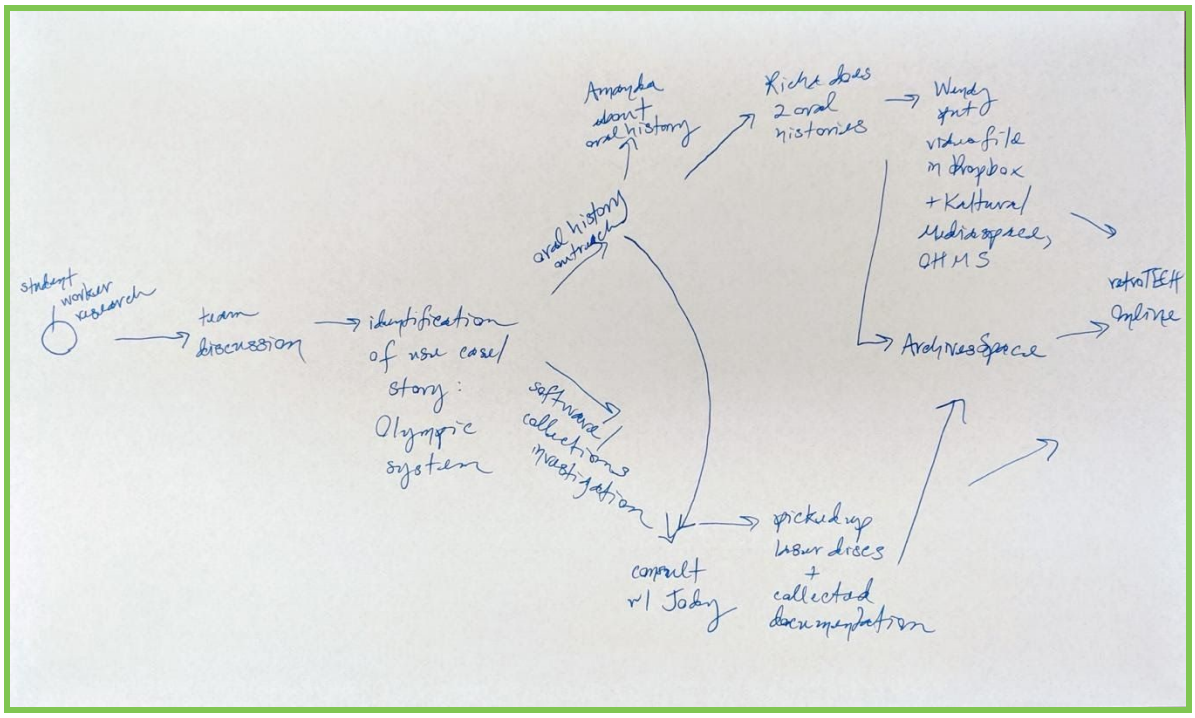
RetroTech

The second field site I visited In July was the Georgia Tech Library's Retrocomputing Lab also known as retroTECH. Located in the Special Collections and Archives unit, this lab's mission is focused on supporting the Georgia Tech campus community in creating the future by exploring and preserving the past with technology. Like the first field site I visited, Living Computers, retroTECH creates exhibit experiences both online and offline that compliment hands-on research of historic computing technology. This service commitment allows for experiential learning and community building through the experience of using, playing, and understanding earlier computing cultures. retroTECH was created after a comprehensive user research study at Georgia Tech, where members of the community expressed interested in creating a library service and dedicated space for students to engagement with hands on vintage hardware and software. The lab is led and managed by my second site champion for three days that I embedded with the team made up of other archivists, library workers, and student research assistants.

Community Driven Emulation...on demand

retroTECH comprises many things—from community crowdsourced-driven exhibits, to mobile emulation "time machines", a special collection of machines and gaming emulators

(amongst many other kinds of machines). It's also a place where GT community members can hangout, relax, and experience a range of gaming stations both emulated and original. This past summer, the Library (staff, facilities, and collections including retroTECH) moved into a newly renovated, renewed library building. The lab's new space is shared with the Data Visualization lab, which allows for an innovative way of providing services, while collaborating with public services and other research librarians. Unlike a computing history museum, or university research archive, the retroTECH lab is nontraditional library service driven by software preservation and on-demand access.



Workflow diagram of community driven emulation

For their FCoP project, retroTECH proposed an online emulation environment where GT users and authorized researchers would be able to use emulated software from the lab's collections for instruction, learning, and research. RetroTECH online will lay the groundwork to build a virtual community to showcase the people of Georgia Tech's impact on the design and development of technology experiences. During my visit I completed 11 interviews where I interviewed public services staff members, archivists, interns and student workers about their roles at retroTECH.

For three days I shadowed my site champion to meetings and got to learn more about one proof-of-concept project called "Cooking Mama Food Fight Game Boy Advance." Cooking Mama is a virtual cooking simulation game that was released for the GameBoy DS in 2006. Since then many spinoffs and new versions have been created, including the "Cooking Mama Food Fight" version at Georgia Tech. The Cooking Mama Food Fight exhibit allows users to access an oral history from a GT undergraduate student who created a game in

Computer Science coursework where students use to design games and compile code using Game Boy emulators.

As I learned more about this first case study, I was able to experience the exhibit myself. With my site champion's help, we used an Everdrive GBA flashcart (a cartridge which allows users to mount an SD card with games) we were able to play the game on a handset at the lab. In addition to the original code, game documentation, and instructions, users will also able to play the game in the retroTECH online using the GBA emulator exhibit. Users can also access a brief oral history of the game's development, motivation, and inspiration from the creator herself, an undergraduate student who created the game as part of her coursework for a computer science degree at GT.

Other retroTECH preservation case studies that I learned about involved an Atlanta Olympic Systems project with data on laserdisc; retroTECH's first community crowdsourced exhibition of vintage computing hardware; and a GT professor's "Ribbit" game, an Apple II clone of Frogger.

Software Preservation with Oral History: Software Stories

Software preservation means different things for different organizations and communities. It may also have different definitions within the same institution, depending on roles and organizational services. For some folks, it can simply mean ingesting software into a digital repository and creating metadata documentation for representation in retrieval systems. This definition relies on potential future users with particular access needs. For others, software preservation can mean hands-on, embodied access by physically encountering hardware and software as material artifacts. We also know that software preservation increasingly may also involve complex arrangements of emulation and more layers of context. For retroTECH and the Georgia Tech community, software preservation with emulation is driven by a new category that they call "stories". These software stories are not only preserved artifacts, or an emulation experience, but the creation of oral histories, prepared for online outreach, and a documentation strategy that involves community members' personal archives to create these "software stories" of computing cultures amongst the Georgia Tech community.

During my interviews and fieldwork observation, and playing with the Cooking Mama Foodfight exhibit in particular, I was able to witness a new genre of software preservation in action, that of the "software story" made up of a documentation strategy, oral history methods, alongside the emulation of the artifact itself. Whether it's a mobile exhibit emulation station, a place to visit, or an online emulator and portal, experiencing retroTECH online and in person revealed to me a commitment to connecting to our past, with a variety of different flavors of software preservation and vintage computing machines with deep layers of context through stories drawn from developers, users, and community members at Georgia Tech.

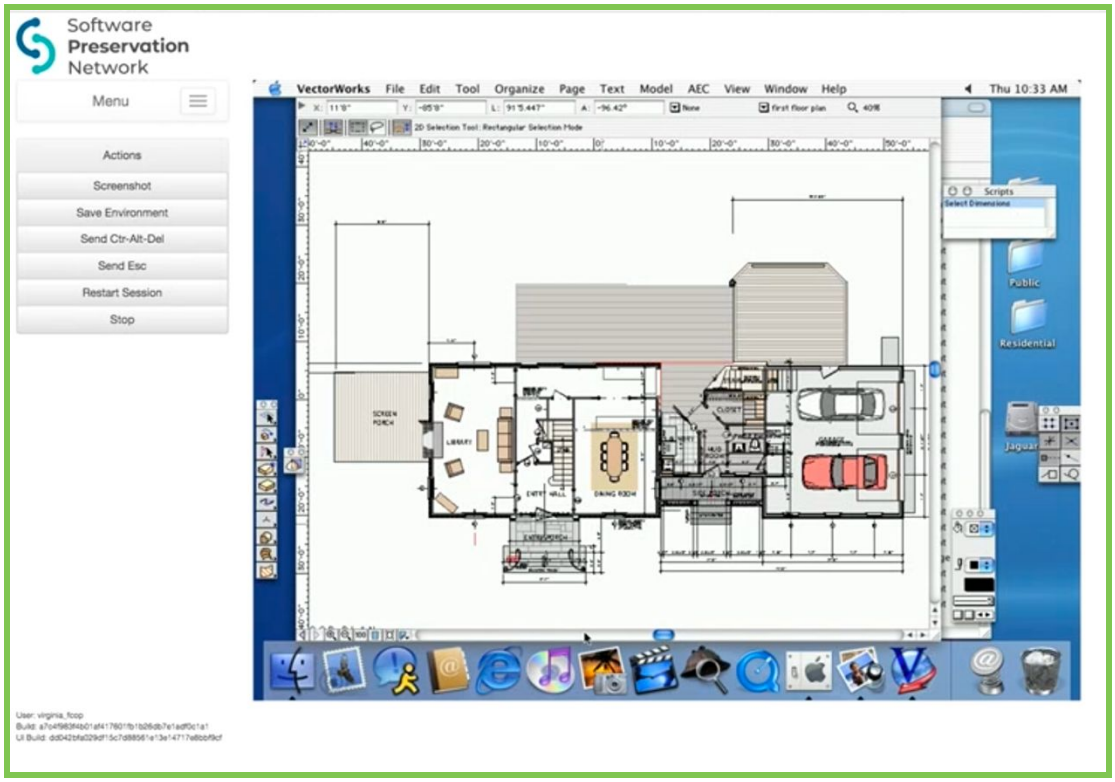
University of Virginia

In August, I was hosted by my third site champion at the UVA Library, where she is the Digital Preservation Librarian and a FCoP team lead for the "Emulation in the Archives" project at UVA. The overall goal of UVA's team project is to share workflows that come from the team's experiences developing and testing approaches for the preservation and emulation of the Peter Sheeran papers. The Sheeran collection is from a local Charlottesville architecture firm, and consists of many software-dependent items, including CAD (Computer Aided Design) files and Building Information Modeling Software. Because the collection includes architecture software with license keys in addition to the software-dependent CAD files for building projects, it has proven to be an ideal case study to test and document workflows using the EaaSI platform [11].

For my visit in Charlottesville, I shadowed the team lead as she collaborated with library colleagues as well as the FCoP team members throughout the library facilities at UVA. I was able to interview a number of staff and team members in the library that are responsible for digital content management, archival processing, and metadata access in support of the library's information services. These interviews and observing team meetings allowed me to learn more about UVA's approach to providing access with adaptable, tested, and well-documented preservation workflows.

Emulation and User testing

A major contribution of the UVA project to the FCoP project has been to design, develop, and document meaningful access experiences to software-dependent archival documents through an emulated environment. With their emphasis on developing workflows, the FCoP team and other colleagues at the library are running user experience research to test users' assumptions about the arrangement, access, and discovery to records in an emulated environment like Mac OS X Jaguar (10.2) alongside their research on administrative and technical workflows for preservation. As part of this work, my site champion and her colleagues integrated a small amount of user testing during an emulation in the archives workshop they ran in July of 2019, and will continue to run some testing through the end of the FCoP project. During my last day, I participated in a user study with my UVA site champion, where I opened a specific architectural plan and tried to find a few layers of the CAD file. We recorded the audio and the screen of this talk aloud session together.



Screenshot of emulation user study exploring CAD files with VectorWorks in OS X

During my user study, I talked through the paths I was taking, poking around the environment, and asking questions about what I hoped to find. While OS X Jaguar was my first operating system environment from college, there were actions and flows in the system I had completely forgotten. In their work on documenting and generalizing these emulation workflows, the UVA team are confronting the challenges of all the different possibilities for providing access. This also includes imagining all the possible kinds of users and the knowledge they will bring to the emulation experience. For example, can we assume that a user will know what the spinning beachball means in the OS X environment? Will a user know how to retrace their steps if they accidentally open an image file in the Quicktime application? These questions, for the UVA team, also include how access and understanding will look from the public services side. How much are staff expected to learn and know about troubleshooting with users in emulated environments? What do sustainable workflows and training look like? How do we prepare researchers for access to these environments?

Saved States: "Just-in-time" and "Just-in-case" Strategies for Emulation

Like most of the preservationists I interviewed this summer, there are many access strategies, but what each strategy may mean for committing support, resources, and attention in anticipation of future users is still open and unknown. Indeed, it will likely involve threading together different born digital workflows, weaving together curation efforts across different preservation experts, and crisscrossing back and forth between

organizational units. In earlier eras of digital preservation research and training, digitization strategies that anticipated what users would need and what they would want to access typically fell on a spectrum between “just-in-time” and “just-in-case” digitization projects. For example, just-in-time scenarios would involve digitizing on a case by case basis, where just-in-case strategies would involve digitizing collections en masse. With software emulation, the challenge of supporting long-term access moves beyond anticipating what people will want and rests in work of maintaining software by keeping it present, or what Marissa Leavitt Cohn calls, “the work of bringing old code together with new, and managing software change in ways that interoperate with legacy systems [28, p. 427].

For their current FCoP use case and grant deliverables, including descriptive workflows, technical workflows, and curatorial checklists, the UVA team has found that the “just-in-time” approach suits some of the current realities and unknowns for software preservation and emulation work. Current versions of their archival description strategy for software is an illustrative example of this idea in practice [29]. In their user experience research and workflow documentation efforts, the UVA FCoP Emulation in the Archives team is gathering empirical evidence to inform preservationists, curators, and archivists in the near future to make decisions and manage what they have termed “saved state” environments for a range of potential emulation experiences. The presentation of an emulation environment to a saved state is a way of presenting multiple narrative forms with emulation, by keeping old and obsolete software present. Creating an emulation workflow that is both technical and curatorially comprehensive is and will continue to be a non-trivial task for software preservationists, like the UVA team. It remains to be seen whether completely emulated collections (just-in-case) or use-driven (just-in-time) emulation experiences will win out as best practices, but in all likelihood, the future of emulation for archival access will involve techniques from both strategies, perhaps even more hybrid approaches to ‘keeping software present’. Software maintainers, like the UVA team and other FCoP cohort members across many sites, are each confronting how software continues to evolve even as they are trying to preserve it in the present for future access scenarios. It is this maintenance of keeping software present and rendering it visible to potential users with emulation scenarios that has yet to be researched, standardized, and theorized in contemporary approaches to software preservation.

Themes across sites

Overall, each of the field sites had different cultures of teamwork, documentation, and user services. There were a number of themes that could be observed across each site:

1. Knowledge about emulation practices
2. Emulation encounters
3. Communicating emulation services

Here I recap each of the themes found in and across sites, provide some illustrations and context for definitions, and then offer some recommendations about how these findings could support future capacity building, research, standardization, and funding efforts.

Knowledge about Emulation Practices

Libraries, archives, and museum institutions preserve, curate, and provide access to their collections in many different ways. Overall, when observing emulation practices at different sites, I found knowledge about emulation playing out in different, but interconnected ways as emulation practices were planned and initiated. These emulation practices may be understood as nested practices that begin at the center and radiate out (Figure 1).

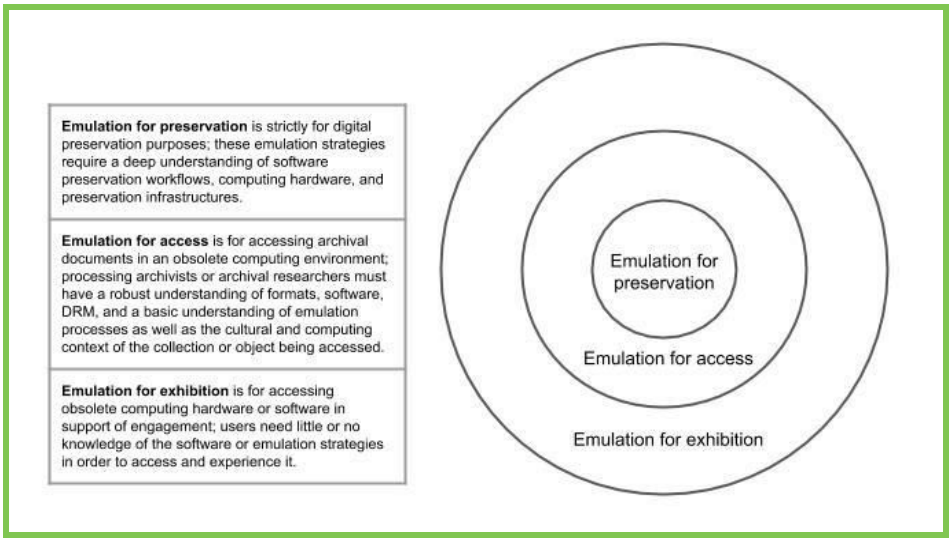


Figure 1. Types of emulation practices.

The first kind of practice, "emulation for preservation" is in support of pure digital preservation—for example copying disk images, accessing bitstreams or making preservation copies. These practices are involved in existing preservation workflows and

involve a deep understanding of emulation as a conceptual process, techniques, and a series of problem-solving tactics. Emulation for preservation also involves a broad knowledge of computing hardware, software, computing cultures in the past, storage formats, even legal policies like DRM or software licensing.

I observed preservation emulation practices at all three sites, but often delegated as a core responsibility for one team expert as part of their work accessioning, describing, or cataloging software materials into the collections. When witnessing emulation for preservation in practice, experts often described this work as a kind of “time traveling”, discovery, and mysteries to be solved, most work was approached as open-ended with roadblocks anticipated. This action language is often because emulation for preservation is often done on a case-by-case basis, which then results in experiential (and usually singular) knowledge gained by the expert carrying out the task or if the time it will take can’t predicted. Emulation with the goal of preserving a disk image for example, involves planning for unknown and unpredictable results—often repeating serialized trial and error work in order to refine the proper tool chain to successfully accomplish the digital preservation goal.

The second layer of emulation practices involves using emulation in support of archival access. By “archival access” I mean the processes that are related to traditional archival access and contemporary experiences of accessing digital archives, primary sources, and special collections. These practices typically are concerned with issues of description, providing access (virtually or physically in a reading room), public services, and the actual delivery process, as well as the policies and information sources that are used to communicate that to the intended users.

Emulation for archival access assumes two layers of expertise in order for an access experience to successfully be achieved. First, those who support representation and access systems—archivists, catalogers, and metadata librarians must describe what has been emulated and what can be meaningfully rendered in providing access to these collections. Second, emulation for access presumes an archival user who engages with software or software-dependent information in order to do their research so that once the information has been successfully emulated they can carry out their typical research practices of confirmation and discovery.

A third type of emulation practice can be seen in those strategies used for exhibition and display engagement, typically found in museums or in display exhibits curated by archives. Emulation in support of exhibition may serve users with brief encounters. These tend to be the most abstracted with the most restricted access, but these encounters and underwritten by the proceeding emulation practices of preservation and archival access in order for exhibition to succeed in rich sense-making of the software or hardware reception process.

Recommendations

1. Specific case study pilots should be designed and documented in different institutions that engage with multiple "access points" illustrating how documentation and workflows span across all the three types of emulation practices
2. Explore the development of standardized documentation, prototyping workflows for different emulation methods (processing and description, preservation, research, exhibit and display)
3. Convene research working groups focused on studying various coordination of emulation practices (at the preservation, research, and exhibition access layers)

Emulation Encounters

As described in the field dispatches, each of these interconnected emulation practices support many different users in possible "emulation encounters". In addition to the types of users I observed, Table 1 describes the varying conditions of access and motivations for possible emulation encounters in libraries, archives, and museums that were witnessed during my fieldwork.

Types of Users	Emulation Encounters
Preservationist users are experts that use emulators in their day-to-day work	• Using emulation to extract a bit stream of software from a floppy disk to maintain a preservation copy of the software for the collection • Creating a hardware emulator of a peripheral device for a computing machine in the collection for intended archival users • Using a disk emulator to make a copy of a video game for exhibition users
Archival users are those that use emulation for their research accessing software-dependent materials	• Using a virtual machine to run an historic operating system, examine file directory structures and open a proprietary • Using an emulator to explore a virtual environment for designing and running game simulations • Listening to a "software story" or oral history featuring a creator describing the motivations for developing a digital experience with software
Exhibition users are those that encounter software emulation in artificial exhibition experiences or computing displays	• Playing Oregon Trail using a floppy disk emulator • Using an Apollo II flight simulator at a space center's visitor center • Playing a cloned arcade game in an exhibit on the video game design

Table 1. Types of Emulation Users and Encounters.

Preservationist users Conceptually, preservationists who use emulation for archival preservation draw upon a lot of "time travel" techniques described earlier, because there are many layers of things that need to work together in order for the preservation outcome to be an authentic, reliable, and trustworthy preservation copy, while weighing out the costs, time constraints, and labor resources. The typical emulation for preservation "user" is an expert digital preservationist, who has advanced training as an information professional or staff member whose institutional role is to preserve software-dependent content as part of their role in service provision.

Archival users As mentioned above, emulation for archival access assumes a user with a more robust understanding of emulation, so the researcher or hobbyist intending to access materials knows the software need based on the format and needs an access point that the archive, university or museum is providing. This user is usually a historian, a scholar, a researcher, a hobbyist, or a fan and they know what the emulation will provide (e.g. "I want to play Ghostbusters 1989 PC game in my browser" or "I want to look at legal briefs created in the Word Star format"). These users may also be archivists themselves, who are responsible for describing, cataloging, and providing access to collections dependent on software. In addition to having a good sense of how emulation enables one to access software or software-dependent objects, these archival users must also have expert or personal knowledge of the contexts that the collection was created in as well as the computing culture of the era, for example office technology or personal computing practices of the creators.

Preservationist users, their knowledge, service provision support, and preservation practices are essential for emulation in support of archival users to be successful in their pursuits. Indeed, most archival users themselves are subject specialists and researchers concerned primarily with the evidence stored in the software-dependent object as an archival document, more than the technical processes necessary for them to access it.

Exhibition users In the case of those people who encounter exhibitions featuring software emulation, emulation typically is in support of broad, public engagement and it is not necessarily important for the individual patron, visitor, or user to know how emulation works or that it's even undergirding the experience of engaging with obsolete software or hardware. Consider a third grade class visiting a museum of technology—it is not a priority to confront the abstraction of virtualizing software for an emulated Oregon Trail game on an Apple IIe. Instead, emulation for exhibition emphasizes an experiential encounter with an earlier or historic computing experience that may be unknown and unfamiliar to the user. In most cases, the original look and feel is prioritized to support sense-making over the knowledge that the encounter involves emulation or a virtual layer. Exhibitions assume patrons from all backgrounds and all ages. So, exhibition users are laypersons, who may be involved in sense-making encounter—such as touching, feeling, figuring out the interface as they encounter the artifact.

Recommendations

1. User studies are needed to understand the different kinds of user backgrounds (from experts to novices), their motivations for encountering emulated software, and their sense-making processes after they have engaged in an emulated computing experience

2. Insight gained from these user studies should be used to inform educators and exhibit designers about the common knowledge people bring to emulation encounters

3. Convene working groups of catalogers, metadata librarians, and processing archivists to share and recommend descriptive standards that support universal access to emulation experiences

Communicating Emulation Services

Each FCoP team that I interviewed and observed described challenges in communicating emulation as typical access services in their organization. As described earlier, each site had different vocabularies and documentation strategies for their workflows, but as I interviewed participants and asked them to map out their workflows, many became aware of the gaps and realties of what institutional workflow documents do reflect and what processes have not been recorded as yet or become well-defined work. In observing teams' communication strategies and the coordination of emulation services, I observed the following.

Prescribed and ad hoc workflows For some tasks, preservation challenges, and team goals, planning and documenting workflows in advance were tools of coordination. But for some emulation projects, workflows were created as they became necessary for particular purposes. For example, the "just-in-time" approach that UVA described was witnessed across each site when there was a particular emulation problem that a team needed to accomplish on demand. During interviews across sites when I specifically asked about workflows and how designating tasks and support was coordinated amongst units, some interviewees discussed gaps between workflow documentation and on the ground capacity. Some well-documented workflows may have been prescriptive as institutional norms, taking on the treads of earlier preservation projects accomplished by the organization, while other emulation tasks needed completely new, ad hoc workflows 'from scratch' each time a new problem was confronted and then tasked. Generally speaking, each site appeared to work back and forth between prescribed and ad hoc emulation workflows in their coordination of resources, team expertise, and institutional priorities.

Chains of documentation Each site appeared to have document-driven practices based on professional best practices as well as organizational mandates. For example, all sites aimed to have catalog records and descriptive information about software and software-dependent collections. While some sites put an emphasis on software manuals, developer's documentation, and use logs when describing software holdings. Other sites emphasized the context of the software-dependent materials, such as interviews with creators, intake information from donors, or supporting materials explaining the context for the software-based works. RetroTech's organization has a breadth of expertise in oral history methods, so their unique contribution to descriptive documentation called "Software Stories" gave another layer of context by capturing creator's own stories about how the software came to be in their motivation, approach, and goals for the software being preserved through emulation.

For many of the case studies there is little to no previous literature about the emulation processes necessary for preservation and access goals, so teams and their leaders are responsible for problem-solving and carefully documenting their approaches for the benefit of their organization, the FCoP project cohorts, as well as future preservationists in cultural heritage organizations. Many of the participants interviewed captured their problem solving efforts in a variety of ways—from lab notebooks, to collaborative team tracking tools using Air tables and Google sheets, to draft manuals intended for future student worker instruction and internship projects. These documents, often described as "notes," and "just drafts," while informal and non-standard, are no less important than formal workflow documentation. Informal documentation captures 'on the ground' experiential knowledge generated and gained in describing case study tasks, from action to action, in practice and eventually in communicating emulation services to future users downstream.

Formal documentation (such as manuals and exhibition information), added descriptive layers of context (such as oral histories and archival description), combined with informal documentation capturing experiential knowledge, notes from experiments and observations from "detective work" are essential in identifying the typical problems and possible outcomes of emulation case studies that then will then inform reasonable pacing for this work, goal-setting for teams, and allocating staff time and expertise to providing emulation services.

The need for a generalized vocabulary Perhaps the most challenging—and thought provoking—outcome of this research were the gaps in vocabulary that came from interviews conversations about emulation practices. In over 25 interviews and almost all team meetings observed there would occur a moment, sometimes many, where a concept, action, task, or abstraction resulting from an emulation encounter or in preparation for emulation where a gap in vocabulary would appear. Many of these gaps or 'missing' vocabulary words come from issues in representing an abstraction of temporality in emulation processes.

For many interviewees, even emulation experts such as engineers and software developers, emulation as a category of access is quite hard to describe because it involves many layers of experience of interaction in order to 'bring software present'. Further, the emulator itself, as a frame, as a tool, and as software can complicate this process of getting to or providing access to some code, information, or software-dependent experience.

Most participants responsible for curation, description, and evaluating long-term access described present and near-term challenges with description for intended users—that is, should we develop access to emulation services if our users may not know what emulation is. Others speculated about how much descriptive information about the emulation process is needed, helpful, exhaustive, or possibly too much, for potential users, especially those who use archives material in their research. If describing the general processes of emulation to a novice is a challenge to information professionals, then representing access as a process with specific emulation techniques in access systems (like a catalog or a finding aid) is even more difficult. As a result, most participants described access in terms of a range of time—instead of describing access as a discrete information encounter, they often depicted emulation actions over a span of time, conveying them as "user sessions".

Recommendations

1. Based on informal documentation practices and self-study, develop open community resources for capturing and documenting informal notes from experiments, "detective work" and ad hoc workflows

2. Prioritize the development open workflows and descriptive standards for documentation and representation featuring emulation case studies for different encounters (preservation, archival access, and exhibition)

3. Conduct studies that explore whether an emulation encounter can be used to improve users' perceptions of temporality and the abstraction of "user sessions"

4. Convene a working group to develop a generalized vocabulary of emulation concepts based on the significant properties of emulated software experiences.

Next Steps: Providing Emulation Access Experiences

All encounters with emulation practices reveal multiple layers of time between the now, and the past of software being made present—this temporality is difficult to describe because it captures an access experience and not just a single entry point. Ultimately, the problem of reconciling layers of time is at the heart of emulation-driven access to software objects. Unlike accessing a book or providing access to a unique artifact in a collection, emulating software-dependent information involves many layers of abstraction, pacing, moving between different layers of time. And so, providing emulation services is ultimately about providing experiences of access in addition to providing access to information through different layers of time (what Stewart Brand calls the "pace layering" found in complex systems [30]).

Many interviewees, and team leads in particular, speculated about how these "access experiences" should be described and captured as information artifacts themselves: How do we convey to a user who is having a "user session" where the actions of the original creators' end and the preservation decisions of the archivist begin? Should users be able to return, capture, or cite processes they encountered in such user sessions? If yes, how? Or should they have access to code, or logs of commands taken, or possibly snapshots of the beginning, middle, and end of emulation sessions? Such snapshots would give users the ability to consider paths taken and not taken during user sessions, or to compare to the historical subject's experience of the software at the time of creation and use. Some interviewees suggested that preservationists should anticipate, or even curate, the most desired paths of those encountering emulation given how time consuming the initial orientation to an emulated experience can be. Many of these descriptive speculations reveal a tension in the differences between providing access to objects such as books or digitized materials and providing access to emulated experiences. It is clear that a more generalized vocabulary that addresses "the when of emulation" and pace layering of emulation practices is necessary in order for LAMs to provide access experiences, document ongoing workflows, and generate robust description to these access points as they do now.

This exploratory research project was motivated by asking questions about emulation processes and if their access outcomes were specified by the unique environs of each place observed. Overall, findings from each site revealed that amongst three ongoing software preservation programs, emulation practices can be motivated by different preservation and access mandates, but ultimately these practices are interconnected, radiating from expert knowledge about emulation as a process to passing encounters with emulators 'hidden' behind artificial computing experiences. Each of the emulation practices identified in this research supported encounters. Different emulation encounters will prefigure

possible use cases and more user studies are needed to enfranchise diverse user populations while communicating the methods and goals of software emulation.

This report has sought to lay out some future directions for research by presenting some interconnected challenges and recommendations for stakeholders concerned with providing access to digital information with emulation strategies. With more initiatives like the FCoP project, which brought together cohorts and enabled research like this investigation, more emulation encounters can be characterized, assessed, and described accurately. Sharing these findings—in documentation, amongst community networks, to administrators and resource allocators will reveal more challenges for communities of practice to consider, confront, and encounter as we preserve and access the past together.

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