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Abstract

In this chapter, we discuss the research opportunities for historical studies of apps and platforms by focusing on their distinctive characteristics and material traces. We demonstrate the value and explore the utility and breadth of web archives and software repositories for building corpora of archived platform and app sources. Platforms and apps notoriously resist archiving due to their ephemerality and continuous updates. As a consequence, their histories are being overwritten with each update, rather than written and preserved. We present a method to assess the availability of archived web sources for social media platforms and apps across the leading web archives and app repositories. Additionally, we conduct a comparative source set availability analysis to establish how, and how well, various source sets are represented across web archives. Our preliminary results indicate that despite the challenges of social media and app archiving, many material traces of platforms and apps are in fact well preserved. We understand these contextual materials as important primary sources through which digital objects such as platforms and apps co-author their own 'biographies' with web archives and software repositories.

Keywords

platforms, apps, web historiography, web archiving, app archiving

Introduction

Contemporary digital objects, such as digital platforms and mobile apps, pose significant challenges to archiving and research practice. With millions or even billions of monthly active users, some of those platforms and apps are among the most popular products and services around the world (Statista, 2017; Statista, 2019). Yet, despite their social, economic, and cultural significance, many of their histories are at risk of getting lost. As a result of rapid release cycles that enable developers to develop and deploy their code very quickly, large web platforms such as Facebook and YouTube change continuously, overwriting their material presence with each new deployment. Similarly, the pace of mobile app development and deployment is only growing, with each new software update overwriting the previous version.

In this chapter, we consider how one might write the histories of these new digital objects, despite such challenges. We reflect on the materiality of platforms and apps as specific types of digital objects and outline a method to take inventory of their archived materials for historical studies. As we argue, these archived sources offer various opportunities for historical studies of platforms and apps. That is, the routine overwriting of digital objects and their data through continuous incremental software updates constitutes both a core problem as well as a source of research opportunities for historians – at least, as long as those changes are documented by these digital objects themselves or preserved by web archives. We, therefore, look into the source availability of preserved material traces of platforms and apps.

In the first section, we consider how, from a material perspective, platforms and apps are different from other digital objects such as websites. As a consequence, there are challenges with regard to their archiving and study as well as new opportunities. In the second section, we describe a method of taking inventory of the available materials for writing platform and app histories. The method is not just useful for building corpora of historical platform or app sources but also potentially valuable for determining significant omissions in web archives and for guiding future archiving practices. In the third section, we describe the outcomes of an exploratory case study of the availability of leading platforms and apps today. We conclude with a reflection on the future of platform and app historiography.

The archived materiality of platforms and apps

The early web mainly consisted of websites and interlinked web pages. As a consequence, the website has become the main unit of archiving as well as the main unit of historical analysis (Brügger, 2018). However, in the past decade, we have witnessed the emergence of new types of digital objects, in particular, digital platforms and apps for social media and beyond. But what characterises these specific digital objects as archived objects, as compared to the website or web page?

When thinking of how platforms and apps are archived today, we contend that we need to consider their specific materiality. With the term materiality, we refer to the material form of those digital objects themselves as well as the material circumstances of those objects that leave material traces behind, including developer resources and reference documentation, business tools and product pages, and help and support pages (Ankerson, 2012; Fuller, 2008; Gillespie, 2003; Kirschenbaum, 2003). Furthermore, developers commonly keep changelogs, release notes, and do versioning. Importantly, rather than secondary sources, which are commonly used for web histories of platforms and apps (Brügger, 2015; Poulsen, 2018), these materials are primary sources that offer particular research opportunities or that may be supplemented and triangulated for accuracy. These material traces may 'tell stories' about the evolving production, preferred usage and embedded politics of software objects (Gillespie, 2003).

We understand these contextual materials as important primary sources through which digital objects such as platforms and apps write, or indeed overwrite, their own 'biographies', thus building on the emerging genre of media biography, including 'software biography', 'website biography', and 'platform biography' (Burgess & Baym, 2020; Natale 2016; Rogers, 2017; Pollock & Williams, 2008). The dual materiality of platforms and apps, as software objects and as sets of material contextual traces, opens up a productive avenue for historical analysis. Even when a platform or app as such is not archived, we may turn to web archives to look for their contextual material traces instead. These traces 'provide a potential entryway to the web cultures, production practices, and symbolic systems informing lost cultural artifacts' (Ankerson, 2012: 392). Furthermore, these 'textual supplements are perhaps even more potent because they seem

to be part of the tool itself' as they document a 'self-interpretation' of the software object that we may employ for its history writing (Gillespie, 2003).

Web archives

The materiality of a web platform manifests as a collection of interrelated web pages that are meaningfully arranged to address different groups of users on different 'sides'. That is, platforms are programmable infrastructures as well as digital intermediaries that bring together different groups of users (Gillespie, 2010; Helmond, 2015; de Reuver, Sørensen, & Basole, 2018). For each user group, there are different sets of resources and documentation that describe the operational logics, stakeholder relations, and preferred uses of a platform. For example, social media platforms provide such materials for their various user groups, which include end-users, developers, businesses, advertisers, partners, creators, media and publishers, politicians, investors, and researchers. As we have outlined previously, these different sets of materials are well archived and afford and privilege different types of social media and platform history (Helmond & van der Vlist, 2019). To locate historical platform resources and documentation, we may turn towards web archives.

The materiality of apps is different from platforms. While many digital platforms exist principally on the web and operate tools, products, and services on multiple 'sides' to different groups of users, apps are software bundles (or packages) that are downloaded directly on to mobile devices from app stores. In contrast to websites and web platforms, mobile apps are not web 'native' and instead reside on mobile devices and in app stores, which makes them even more difficult to archive and study. Yet they are entangled with a variety of other web services (Dieter et al., 2019). App stores, arguably, are a 'native' environment for apps. For end-users, apps present themselves as contained digital objects that are purchased and downloaded from platform-specific app stores, such as Google Play for Android or the App Store for the iOS operating system. Yet by their design, app stores only provide access to the latest version of an app bundle and not to former versions. With each new software update, a former app version is overwritten – both inside the app store and on the user's mobile device. As a result, neither app

stores nor mobile devices keep former versions of apps, which poses challenges for historical app studies.

App repositories

To locate former app bundle versions, we may turn to several third-party software repositories, such as Cydia for iOS apps or APKMirror for Android apps.[1] Contrary to traditional institutional archives, these repositories are non-institutional storage locations for the retrieval of software that were never designed for permanent preservation (Allix, Bissyandé, Klein, & Le Traon, 2016). While they may share commonalities with archives, software repositories do not curate collections of 'records' for permanent historical preservation and do not necessarily consider their value as evidence or as a source for historical research (Brügger, 2018). Additionally, the use of software repositories as app archives raises issues with regard to archive incompleteness and software insecurity. They are incomplete because they rely on users manually uploading app versions; they pose security risks because not all repositories scan package uploads for malicious code injections. When app code is tampered with, this may directly limit or influence historical code-based analyses. And even if we find former app versions in repositories, we still face software emulation challenges with apps as they typically require a complex set of dependencies and will only 'run' or operate on specific devices and operating systems of the past (Boss & Broussard, 2017; Helmond & van der Vlist, 2019; Stevenson & Gehl, 2018).

As an alternative or additional strategy, app historians may turn to archived app metadata sources as preserved in web archives that hold 'snapshots' of app details pages in app stores or repositories. While apps and app stores both exist primarily on mobile devices, the leading app stores – Google Play and Apple's App Store – also provide web-based graphical user interfaces to their stores. These stores contain a wealth of information about specific apps as well as their relations to other, 'Similar' apps, and the store categories or app collections to which they belong (Dieter et al., 2019). For each app, there is a details page with the app's title, developer, bundle version, screenshots, description, requested app permissions, download statistics, reviews, ratings, and more. Fortunately, these app store details pages are preserved in web archives, which generates opportunities for historical app studies. In short, to locate historical app materials, we

may thus either turn to app repositories to retrieve former app versions or to web archives to retrieve contextual information.

Assessing the availability of platform and app sources

To determine whether these materials have been preserved, and where they are located, we conducted an exploratory study of the availability of archived sources for platform and app history. Building on previous work (Helmond & van der Vlist, 2019), we first detail a method for assessing the availability of archived web sources for platforms and apps in web archives and app repositories.

Making use of market data portals Statista and AppAnnie, we selected the current top-20 most popular social media platforms and top-10 mobile apps for Android and iOS combined, both based on the current number of active users worldwide (App Annie, 2019; Statista, 2019). For the first source set of social media platforms, we made an inventory of their most prominent 'sides' and created a list of URLs pointing to the location of their principal materials (for example twitter.com, developer.twitter.com, business.twitter.com, marketing.twitter.com, investor.twitterinc.com). For the second source set of mobile apps, we created a list of URLs pointing to the app store details pages for each app.[2] These URLs contain the unique bundle identifier of each app, which remains stable even when apps are continuously updated and overwritten. App store links are constructed with these bundle identifiers and thus also remain stable over time.[3] So, although apps are updated continuously, they have a stable bundle identifier and a stable web URL that points to a details page that we may track in archives over time. In addition, we used these unique bundle identifiers to locate these apps in ten prominent third-party software repositories for Android apps.[4]

To assess which web archives actually hold archival records of a particular resource, we employed Memento's Time Travel Service (Van de Sompel et al., 2009).[5] The service functions as a search engine 'on top of' the 25 leading international web archives, and may be queried for specific URLs (Memento, 2016).[6] For end-users, it offers a graphical user interface (GUI) that may be deployed to manually query and locate a URL across multiple web archives. Additionally, it offers an application programming interface (API) to programmatically request

that data. Both methods return a list of web archives that hold one or more Mementos (i.e., time-stamped archived copies of a specific URL). For each Memento, the service returns the first and last Memento available as well as links to all available captures across archives. Time Travel thus provides a simple method to assess the availability of specific archived sources across web archives. To determine the total number of Mementos held or the number of archives holding them, users may follow the 'All captures from' link for each web archive and manually count the number of Mementos held.

To scale and automate this process for a large source set of URLs, researchers may use MemGator, an open-source command-line interface utility that is built 'on top of' the Memento API and aggregates Mementos.[7] MemGator programmatically requests Memento TimeMaps from a list of web archives that support the Memento protocol (Alam & Nelson, 2016). Each TimeMap provides a time-stamped list of all Mementos held in that archive for a given URL (Memento, 2015). It also lets researchers customise the list of web archives from which to request TimeMaps. For present purposes, we extended MemGator's list of web archives that natively support the Memento protocol, as specified in 'archives.json', with a number of web archives listed in the Time Travel Archive Registry that run Memento proxies (Memento, 2015), so as to be as inclusive as possible in our exploratory study. Our custom list included 20 web archives from which to programmatically retrieve data. More specifically, we used MemGator to programmatically retrieve the available platform and app materials from across these 20 web archives and then analysed the results to assess the availability of sources.[8] In what follows, we describe the results of our exploratory study.

The availability of platform and app sources

We analysed the source availability of platform and app materials according to three criteria: first, the volume of availability or the total number of Mementos held; second, the depth of availability, specified as the number of days, months, or years between the first and last Mementos; and third, the breadth of availability, referring to the number of web archives holding those Mementos (Helmond & van der Vlist, 2019). The first two criteria determine the amount of available material and the possible levels of granularity for historical analysis, while the third

criterion enables researchers to triangulate and verify historical sources, such as when certain elements are corrupted or missing.

In Tables 1–2, we provide a summary of our exploratory study results. For both of our source sets, we counted the total number of Mementos held across web archives (i.e., volume), counted the number of web archives holding those Mementos (i.e., breadth, expressed as a single number up to 20 web archives), and determined the time span between the first and last Mementos held (i.e., depth, expressed in number of days). Taken together, these three dimensions provide a useful account of source availability and allow researchers to determine the feasibility of certain historical projects or allow archiving practitioners to reconsider their archiving strategy. Based on these counts, we then calculated an availability rank for each platform and app by calculating the number of captures per day (volume divided by depth) and then multiplying that number by breadth. The outcome values have been ranked in ascending order.

Social media platforms in web archives

As we have analysed elsewhere, social media platforms have been relatively well archived on all of their 'sides' (Helmond & van der Vlist, 2019). The five best-archived social media platforms represent an average of 913,440 Mementos, followed by an average of 130,036 for the next 15 platforms (Max = 1,783,855; Min = 3,007; Median = 166,412).

As these results suggest, there are many opportunities for historical platform studies about different 'sides' and user groups, albeit at different levels of granularity, depending on source availability. In particular, developer and business materials have been well archived and enable researchers to write histories beyond the 'front-end' interface for end-users. They may look at platforms' influential roles as development platforms, advertising platforms, content creation platforms, media publishers, and platform companies (Helmond & van der Vlist, 2019; Helmond, Nieborg, & van der Vlist, 2019; Nieborg & Helmond, 2019). These materials also enable researchers to examine how the technological architectures and economic business models of platforms evolve side-by-side. In short, platform histories would benefit from considering more than just their end-users and contents and include their multiple user groups to examine how they coevolved with respect to other 'sides'.

App details in web archives

Contrary to most popular social media platforms, apps have been less well archived in general, at least when we look at the preservation of their app store details pages in web archives (Table 1). For Android apps, Facebook Messenger is the best-archived app by far, leaving all other apps behind. In fact, other apps have hardly been archived at all. While the four best-archived top Android apps – Facebook Messenger, Instagram, Facebook, and WhatsApp Messenger – represent an average of 27,681 Mementos each, the next six top apps have an average of just 98.6 Mementos (Max = 85,222; Min = 24; Median = 240). For top iOS apps, Facebook Messenger accounts for nearly 99,581 Mementos while the next 9 top apps have an average of just 177.4 Mementos (Max = 99,581; Min = 0; Median = 85). In particular, pages of non-Western apps have been poorly archived, in line with a previously-identified imbalance of source availability in archived websites between the United States and other countries (Thelwall & Vaughan, 2004).

The archived app materials enable researchers to examine the evolution of individual apps, or app collections and genres. In a previous project, we examined the emergence of secure or encrypted messaging and chat apps on Android and used their descriptions to determine how those apps offered new and different ways of 'doing privacy' (for example the emergence of new encryption protocols, and tradeoffs between security, privacy, and usability). Tracking app descriptions over time thus enabled us to understand how apps or app developers responded to Edward Snowden's surveillance revelations in June 2013, when digital surveillance became a 'matter of concern' on the web and mobile ecosystem (Dieter et al., 2019; van der Vlist, 2017). App details pages enable app historians to tell stories about an app's rhetorical positioning (for example using taglines, descriptions), production (for example using developer names, app versions, changelogs), distribution (for example using app collections, relations, pricing models), and reception (for example using app downloads, reviews, ratings).

Table 1 Availability of archived web sources for top 10 Android and iOS apps across web archives (accumulated).

app title	Android (Google Play)				iOS (App Store)			
	volume	depth	breadth	rank	volume	depth	breadth	rank
Facebook	8,198	2,637	8	3	390	3,389	6	4
WhatsApp Messenger	4,092	2,600	7	4	548	3,395	6	2
Facebook Messenger	85,222	2,638	10	1	99,581	2,708	9	1
WeChat	442	2,557	5	5	120	3,019	4	5
Instagram	13,215	2,611	11	2	447	3,153	6	3
QQ	38	2,551	1	8	16	2,547	1	8
Alipay	26	2,188	1	9	26	800	1	6
Taobao	31	2,147	2	7	50	3,168	1	7
WiFi Master Key	31	1,890	3	6	0	0	0	n/a
Baidu	24	2,196	1	10	0	0	0	n/a

App bundles in app repositories

With regard to the preservation of Android app bundles in third-party software repositories, we found more promising results (Table 2). All of the 10 top apps in our set are relatively well archived based on all three criteria. In terms of volume, the four Facebook-owned top apps – WhatsApp Messenger, Facebook, Instagram, Facebook Messenger – have been stored an average of 3,722 times while the next six – all non-Western – top apps have been stored 297 times on

average (Max = 4,585; Min = 166; Median = 469). The oldest versions of the apps in our dataset date back to May 2012.

These results suggest that app repositories are promising sources for historical app studies, both to study app bundles themselves and to triangulate app details between app repositories and official app stores. Most importantly, these primary app materials enable researchers to devise historical methods based on 'static' app analysis (Dieter et al., 2019). That is, app bundles may be decompiled and analysed as source code to study requested app permissions, embedded code, and external relationships to other infrastructural web services such as advertising and content delivery networks, for example (Gerlitz, Helmond, Nieborg, van der Vlist, 2019). Or, researchers may emulate those app bundles to conduct 'dynamic' app analysis and study evolving interface design patterns and the network connections that mobile devices establish on behalf of apps.

Table 2 Availability of top-10 Android apps across app repositories (accumulated).

app title	**Android**			
	volume	**depth**	**breadth**	**rank**
Facebook	4,585	2,584	9	2
WhatsApp Messenger	4,268	2,585	10	1
Facebook Messenger	2,765	2,609	10	4
WeChat	315	2,364	10	6
Instagram	3,271	2,600	10	3
QQ	229	2,187	9	9
Alipay	193	1,362	8	7
Taobao	258	1,844	7	8
WiFi Master Key	623	1,401	8	5
Baidu	166	2,242	5	10

Conclusion: Platform and app historiography

In this chapter, we have demonstrated how researchers may use web archives and app repositories to write histories of new digital objects such as platforms and apps, despite their archiving challenges. We have reflected on the materiality of platforms and apps as specific types of digital objects and have outlined a method to make an inventory of their archived materials. Existing archived sources offer many opportunities for historical platform and app studies and it is our hope that their affordances for research are further explored.

Our exploratory study of source availability for the most popular social media platforms and mobile apps provides important insights into the current state of platform and app archiving, which should be of interest to researchers and historians of web platforms and mobile apps. Furthermore, our assessment of source availability provides relevant starting points and example case studies for different types of platform and app history and may guide future historians in the process of corpus building. Our exploratory study should also be of interest to web and app archiving practitioners. In particular, our source availability assessment method and the preliminary results of our exploratory study may guide or inspire a reconsideration of archiving efforts going forward. Current web archiving strategies or protocols may not capture all of the relevant materials, as in the case of app store details pages which are located deep within app stores. We particularly recommend a more comprehensive archiving strategy that captures the multiple 'sides' of popular social media platforms and the app details pages of popular app stores beyond the top apps.

Although we only looked at a small selection of top platforms and apps, we already observed large discrepancies in source availability between both types of digital objects, which inevitably determines and limits the future histories that may be written about and with those apps. Our selection of popular apps is expected to be far better archived than the millions of apps in the 'long tail' of app stores. We should note, however, that even with a hundred or fewer Mementos it is, of course, possible to write the histories of platforms and apps. Depending on the historical project, differences in source availability may have implications with regards to volume (for example limiting the afforded level of granularity or resolution), depth (for example constraining the historical period), and breadth of availability (for example limiting the possibilities of

triangulation or source verification). Existing services and utilities such as Memento and MemGator offer the opportunity to move beyond the Internet Archive as the primary, or even only source of web history. They also enable researchers to triangulate and verify sources and thereby address common issues of archive incompleteness and software insecurity (including corrupt app files).

The ephemerality of digital platforms and mobile apps may be understood as the result of a continuous stream of incremental software updates that overwrite the material presence of a platform or app every time. We may conceive of this process of overwriting as a challenge of material erasure, or as a 'native' mode of software history-writing. That is, even though these ephemeral digital objects change continuously, web archives and software repositories, fortunately, capture many of those changes, thereby arresting the ongoing material transformation of platforms and apps at certain time intervals (for example with hourly, daily, or monthly captures or 'snapshots'). Consequently, we argue that the biographies of platforms and apps are co-written by these digital objects themselves and by web archives, and in the case of apps, also by software repositories. We can employ their different types of primary and contextual sources to 'reconstruct' these processes of overwriting at different levels of granularity – from the minute, incremental changes to the longer-term evolution of a platform or app. We can use web archives and repositories to reconstruct what was written on top of other writing, and narrate the drama of changes, updates, and versions.

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Notes

1. Cydia, https://cydia-app.com/; APKMirror, https://www.apkmirror.com.
2. Over the past decade, app store URLs changed only once or twice: Google Play (since 2012) was formerly called Android Market (2008–2012), and the domain changed from

android.com/market to play.google.com/store; Apple's App Store (since 2008) was formerly called App Store (iTunes Preview) (2012–2019) and before that, Web Apps for iPhone (2008–2012), and its domains changed from apple.com/webapps to itunes.apple.com to apps.apple.com. For our exploratory study, we focused only on the current URLs at the time of writing.

3. App store URLs are constructed as follows: for Google Play, https://play.google.com/store/apps/details?id={bundle_id}; for the App Store, there are three URL formats, https://itunes.apple.com/app/{bundle_id}, https://itunes.apple.com/us/app/{bundle_id}, https://itunes.apple.com/us/app/appname/{bundle_id}.
4. We included the following app repositories: AndroidAPKsBox.com, AndroidAPKsFree.com, AndroidDrawer, APKMirror, APKMonk, APKPure, APKPure.ai, APKPure.co, Aptoide, and Uptodown.
5. Time Travel, http://timetravel.mementoweb.org/.
6. As of June 2019, 'Time Travel Find' supported the following web archives: archive.today, Archive-It, Arquivo.pt: the Portuguese Web Archive, Bayerische Staatsbibliothek, Bibliotheca Alexandrina Web Archive, DBpedia archive, DBpedia Triple Pattern Fragments archive, Canadian Government Web Archive, Croatian Web Archive, Estonian Web Archive, Icelandic web archive, Internet Archive, Library of Congress Web Archive, NARA Web Archive, National Library of Ireland Web Archive, National Records of Scotland, perma.cc, PRONI Web Archive, Slovenian Web Archive, Stanford Web Archive, UK Government Web Archive, UK Parliament's Web Archive, UK Web Archive, Web Archive Singapore, and WebCite.
7. MemGator, https://github.com/oduwsdl/MemGator.
8. All data were collected between May–June 2019.

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