MIS Quarterly

ISSUES AND OPINIONS

THE AMBIVALENT ONTOLOGY OF DIGITAL ARTIFACTS[1]

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Digital artifacts are embedded in wider and constantly shifting ecosystems such that they become increasingly editable, interactive, reprogrammable, and distributable. This state of flux and constant transfiguration renders the value and utility of these artifacts contingent on shifting webs of functional relations with other artifacts across specific contexts and organizations. By the same token, it apportions control over the development and use of these artifacts over a range of dispersed stakeholders and makes their management a complex technical and social undertaking. These ideas are illustrated with reference to (1) provenance and authenticity of digital documents within the overall context of archiving and social memory and (2) the content dynamics occasioned by the findability of content mediated by Internet search engines. We conclude that the steady change and transfiguration of digital artifacts signal a shift of epochal dimensions that calls for rethinking some of the inherited wisdom in IS research and practice.

Keywords: Digital artifacts, digital objects, archives, search engines, information platforms and infrastructures, modularity, reflexivity, change

Introduction

Digital ecosystems feature artifacts and operations that increasingly derive utility from the functional relations they maintain. This is clearly indicated by the growing prospects of combining software and software components and mixing content across platforms, infrastructures, and production systems (Langlois 2003; Merrifield et al. 2008; Yoo et al. 2010). Little wonder, technological artifacts and operations have always occasioned links and functional dependencies of one kind or another. Yet, current technological developments signal a qualitative change. Digital artifacts are intentionally incomplete and perpetually in the making (Garud et al. 2008; Zittrain 2008). Incompleteness is both an opportunity and a problem. It is an opportunity, insofar as it does not foreclose the range of tasks and operational links an artifact can or might accommodate. But it is a problem as well, in the sense of reducing control over the artifact and its use. A modicum of stability has been essential to manageable social orders.

We deploy the term digital artifacts as a means of theorizing this incompleteness. Digital artifacts, we claim, have an ambivalent ontology. They are objects yet they lack the pleni-

[1]Ola Henfridsson was the accepting senior editor for this paper.

tude and stability afforded by traditional items and devices. Our purpose is to shed light on the conditions in which current artifacts are embedded and show the relevance and import of the developments we pinpoint for IS research and practice. While these insights recur in the IS and management literatures (Langlois 2003; Merrifield et al. 2008; Yoo et al. 2010), research on these essential matters is still sparse.

Literature Review

The particular nature of digital artifacts, their essential features, and affordances represent a central theme in a small yet growing literature. Ekbia (2009) portrays digital artifacts (such as blogs, wikis, personal profiles in social networking sites) as lacking a clear identity, a condition he attributes to the constant change they undergo. Artifacts of this sort, he claims, exhibit an ambivalent ontology, violating Leibnitz's law of the identity of indiscernibles (exactly similar but distinct implementations exist) and the indiscernibility of identicals (a large number of renditions are available that are seldom exactly alike). He also describes digital artifacts as performative, constructing social relationships (a blog or personal profile) rather than simply representing something out there. Digital artifacts, Ekbia concludes, lack the stability and adequacy characteristic of traditional objects and are better seen as quasi-objects, a condition whose implications he empirically explores in the context of open source software development. Similar ideas have been advanced by Kallinikos et al. (2010), Kallinikos and Mariategui (2011), and Manovich (2001) who consider digital artifacts such as files, images, and films or videos as fluid and editable, often embedded in complex, distributed, and shifting digital environments. Faulkner and Runde (2009, 2011), on the other hand, have sought to define the identity of technological objects, paying particular attention to the immaterial status of digital artifacts, their reproducibility (very low marginal cost), recombinability, and non-rival nature, and the ways these attributes are implicated in the innovation of products and services.

Some of these ideas recur in Yoo (2010) and Yoo et al. (2010) who describe digital artifacts as reprogrammable and self-referential entities, whose distinct functional make-up is closely tied to what they call *data homogenization*. Resulting from the mapping of signals into discontinuous, binary digits, data homogenization (or digitization) is critical in enabling digital artifacts to develop innovative properties among which figure their decomposability, adaptability, traceability and interoperability. As digital artifacts diffuse, these properties, Yoo et al. claim, become implicated in the making of modular and multilayered digital infrastructures that instantiate the independence of services from devices, and content from the underlying networks. Such condition opens up ample potential for innovation, enabling the mixing of inputs/outputs across the traditional and usually fixed industry borders associated with standard physical products and vertical integration (see also Tiwana et al. 2010).

Cast in different terminology, similar ideas have been advanced by Benkler (2006), Lessig (2006), and Zittrain (2008). Common to all three is the idea of the distinctive make-up of digital technologies epitomized by the end-to-end architecture of the Internet, the modularity of the digital infrastructures and digital devices, and the granular character of the tasks they enable. Zittrain in particular delineates a number of properties of what he calls generative technologies including leverage, adaptability, ease of mastery, accessibility, and transferability, which, taken together, define the functional identity and innovativeness of these technologies. Zittrain describes digital artifacts as being intentionally unfinished technologies to be redeemed by use—a condition that recalls Ekbia's claim of the mutable and ambivalent ontology of digital artifacts (see also Garud et al. 2008). Table 1 summarizes and extends these ideas.

The Constitution of Digital Artifacts

Conceived as objects, digital artifacts differ from physical entities and other cultural records (e.g., paper-based files, tape recordings) of non-digital constitution along a number of dimensions. To begin with, digital artifacts *qua* objects are *editable*. They are pliable and always possible, at least in principle, to modify or update continuously and systematically. Editability assumes various forms. It can be achieved by just rearranging the elements of which a digital object is composed (such as items in a digital list or subroutines in a software library), by deleting existing or adding new elements, or even by modifying some of the functions of individual elements.

In other cases, editability is built into the object in the form of regular or continuous updating of content, items, or data fields, as is the case with digital repositories of various kinds whose utility is closely associated with constant updating (e.g., blogs or wiki pages, transaction or booking systems, currency exchange systems).

Second, digital artifacts *qua* objects are *interactive*, offering alternative pathways along which human agents can activate functions embedded in the object, or explore the arrangement of underlying information items. While ultimately tied to the

Table 1. Literature Overview of Properties of Digital Artifacts

	Yoo (2010); Yoo et al. (2010)	Kallinikos et al. (2010); Kallinikos and Mariategui (2011)	Faulkner and Runde (2009, 2011)	Ekbia (2009)	Zittrain (2008); Benkler (2006); Lessig (2006)	Manovich (2001)
Research Field	Information Systems	Information Systems, Communication and Media Studies	Economics, Organization Studies	Information Science, Information Systems	Economics, Law	Communication and Media Studies
Research Focus	Digitalized artifacts, digital infrastructures	Digital and new media objects, metadata	Non-material technological objects	Digital artifacts	Generativity and innovation	New media objects
Conceptual Affiliation	Design Science, Behavioral Science	Sociology of Information	Transformational Model of Social Activity	Actor-Network Theory	Economics of Social Production, Intellectual Property Rights	Semiotics
Paradigmatic Examples	iPad, the Internet	Digital video	Computer file	Software bug	PC, the Internet, Wikipedia	Database cinema
Attributes	• Programmability • Addressability • Sensibility • Communicability • Memorizability • Traceability • Associability	• Editability • Openness • Transfigurability • Distributedness • Interactivity	• Non-rivalry in use • Infinite expansibility • Recombinability	• Largely unstable • Unbounded • Resisting reification	• Leverage • Adaptability • Ease-of-mastery • Accessibility • Transferability	• Numerical representation • Modularity • Automation • Variability • Transcoding
Conclusions	Digital artifacts are embedded into layered, modular architectures that help separate content from devices and information infrastructures.	Digital files and new media objects are bound up with the ways metadata signifies within the media ecosystem and the conditions that ensure online accessibility, findability and interaction.	Non-material bitstrings separate objects from their material bearers such as CD-ROMs, hard drives etc.	Digital artifacts are quasi-objects defined as processual and relational entities.	Modularity and granularity of tasks and projects as well as the end-to-end architecture of the Internet puts productive activity under the control of the individual and contributes to innovation.	The new logic of individual customization contrasts with the industrial logic of mass standardization.

editable nature of digital artifacts, interactivity is here conceived as distinct from editability in that it does not result in any immediate change or modification of the digital object. Its key quality is information exploration, made possible by the responsive and loosely bundled nature of the items that make up the digital object. In this regard, interactivity enables actions of a contingent nature (depending upon user choice), an affordance that sets digital artifacts apart from the fixed responses of physical objects, and the inert nature of paper and non-digital records. To be sure, all artifacts entail some degree of malleability (Orlikowski 2000; Ulrich 1995). However, interactivity, as we elaborate further below, is closely tied to the modular architecture and loose coupling of the elements of digital objects and the greater degree of freedom these conditions afford.

Third, digital artifacts *qua* objects are possible to access and to modify by means of other digital objects, as when image-editing software is used to change digital images or when content from different sources is aggregated to bring together news headlines. It can also be accomplished in a more profound way, usually by experts or potent amateurs, through accessing the underlying principles or rules of the program that govern the behavior of the digital object or its source code. Digital objects are thus *open* and *reprogrammable* in the sense of being, in principle (if not in practice), accessible and modifiable by a program (a digital object) other than the one governing their own behavior (Kallinikos and Mariategui 2011; Manovich 2001; Zittrain 2008). Tied to change and modification, openness or reprogrammability is accordingly distinct from interactivity. It also differs from editability,

insofar as the latter is confined to the simple reorganization, addition, or deletion of the content and items that make up the digital object or the updating of information (for instance, in a database) without interference on the logical structure (the respective database schema) that governs the object and the mechanisms of information production and processing. Thus conceived, openness is tied to the interoperable character of digital artifacts (Ciborra 2006; Ekbia 2009). It is, of course, a widely diffused social practice to edit written information by means of other information. It is also possible to expand, modify, repair, or destroy a physical object by means of another, or combine two or more physical objects to accomplish a specific task. However, digital objects allow for the much deeper interpenetration of the items and operations by which they are constituted. Interoperability is an important condition of the digital ecosystem (Yoo et al. 2010).

Fourth, as the outcome of interoperability and openness, digital artifacts *qua* objects are *distributed* and are thus seldom contained within a single source or institution. In this sense, digital objects are transient assemblies of functions, information items, or components spread over information infrastructures and the Internet, a condition that sets them strongly apart from physical objects and artifacts of non-digital constitution. The hypertext, for instance, underlying many digital documents is just a network of various Web resources, interlinked by a multitude of diverse and interconnected items, devices, and producers. Distributedness confers digital objects some interesting qualities. Digital objects are borderless. In comparison to packaged and single media like books, they lack inherent borders that bound them as obvious entities. As we elaborate later on, these borders have to be maintained technologically. Furthermore, distributedness makes possible various combinations out of a larger ecology of items, procedures, and programs, a condition that renders digital objects fluid and crucially transfigurable.

The attributes we ascribe to digital artifacts and the contrast to physical or other traditional cultural media may seem overstated. It is well known that digital artifacts can be sticky and unresponsive, entailing path-dependent evolutionary trajectories and lock-ins that resist easy change (e.g., Ciborra 2000). True as these observations may be, they cannot fail a widespread sentiment of digital artifacts being, in principle, if not in practice, far more mutant and changeable than physical artifacts and paper-based documents. Far from being the contingent upshot of factors, the attributes we ascribe to digital artifacts *qua* objects are the systematic outcome of their ambivalent ontology and incomplete nature (Gleick 2011). They stem from the nature of digitality and are further supported by the modularity and granularity of the ecosystems in which digital objects are embedded (Yoo et al. 2010). Let us explain.

Modularity has, ever since Simon (1969),[2] been associated with the organization of items and operations that make up a system in distinct and relatively self-sufficient blocks that allow for independence, within a wider yet loosely coupled network of functional relationships between blocks, mediated through interfaces. As a design principle, modularity represents the technical realization of the simple yet powerful idea that integral, *en bloc* objects or systems are hard to act upon, control, and manipulate. As such, it applies as much to physical as to digital objects (Langlois 2003; Simon 2002; Ulrich 1995). However, modularity runs much deeper and wider in digital objects and technologies. Due to the fixed design features of physical objects, interfaces are by necessity designed as function specific, thus tailored to the particular object or product to which they belong. Spare parts, for instance, of a vehicle manufacturer can seldom fit the vehicles of other manufactures, let alone other products or industries. The negotiation of standards in physical objects or structures can certainly raise the compatibility of their components but can seldom cross the functional boundaries of different industries. These last constitute what Yoo et al. (2010), drawing on Clark (1985), refer to as single product design hierarchies whereby the fixed design features of the final product (e.g., vehicle, appliance) recur across an industry in the form of fixed interfaces of the contributing product components. Digital interfaces, by contrast, can accommodate a much wider spectrum of functions (Kallinikos 2006) and are, not infrequently, designed to be function or product agnostic, as modules that cross particular platforms testify (Tiwana et al. 2010; Yoo et al. 2010; Zittrain 2008). By the same token, one digital interface does not physically stand in the way of other interfaces (Weinberger 2007).

The attributes we ascribe to digital objects are further associated with their granular constitution (Benkler 2006). *Granularity* refers to the minute size and resilience of the elementary units or items by which a digital object is constituted, an idea that is clearly conveyed by the difference between analog (non-granular) and digital systems. While modularity concerns relationships between blocks, granularity entails the stuff of which these blocks are made. The granularity of digital objects derives from their ultimately numerical constitution and the ability this furnishes for tracing composite units deep down to the most minute elements and operations by which they are made (Manovich 2001). Physical objects and, even more so, analog systems are seldom granular. They are made of blocks or elements thus bundled as to be not readily decomposable and traceable down to elementary units (Goodman 1976; Kallinikos 2009). Two blocks of operations set

[2]Simon never used the terms *modular* or *modularity*.

the concept of granularity clearly apart from that of modularity. First, granularity enables pliability by allowing tracing down the functionality of a digital object to several layers of underlying operations (e.g., by being pliable, a database can be data mined, a video edited by video editing software) by which it is sustained. No matter how difficult this may be in practice, it is always, in principle, possible, thanks to the binary and numerical status of digital objects. Second, granularity enables minute and piecemeal interventions, as the widespread practice of digital content editing (e.g., Wikipedia) reveals. The fine-grained nature of digital objects enables people to contribute to collective pursuits under varying circumstances that suit their time availability, capacity, or inclination (Benkler 2006).

In sum, modularity and granularity furnish the generative matrix of the attributes of editability, interactivity, openness, and distributedness. These last are derivative, in the sense of emerging out of a deeper set of relationships characteristic of digital technology. Placed in a larger purview, the making of granularity and modularity to ubiquitous technological principles that rely on data homogenization, von Neumann architecture, and binary computing are remarkable accomplishments (Gleick 2011; Yoo et al. 2010). They confer on digital artifacts new functional capabilities and affordances but they also insert them in continuously shifting relationships that render their manageability problematic. In the next two sections, we outline two fields of contemporary social practice that illustrate the double-edged nature of digital artifacts. The first one is the *archive*. This age-old institution wrestles with novel dilemmas of ordering and preserving digitally born information artifacts. The second concerns *Internet search* and the significance it is acquiring in shaping information seeking practices, as search engines become the primary mechanism for mediating access to digital records.

Archiving the Web

A broad range of practices rely on enduring artifacts (e.g., books, pictures, documents) authenticated, canonized, and collected by dedicated authorities for reasons of documentation, reference, and identity (Allison et al. 2005; Assmann 2008). Content cast in digital form is gradually gaining an equivalent status, becoming worthy of being preserved as records of human activities and historical evidence (CLIR and Library of Congress 2002). However, digital artifacts are in constant flux and thus difficult to preserve over time (Coyle 2008), offering a vivid illustration of the challenges raised by the editability, interactivity, openness, and distributedness of digital objects. Let it be clear that the issue of originality of evidence confronting the archive of digital content transcends archiving as such. It carries wider implications that are closely associated with the ways digital objects are identified, bound, stored, accessed, and reused.

Archives have played a crucial role in preserving original evidence and continue to do so with respect to digital content, in general, and webpages, in particular (Lyman 2002). However, the two key principles of archival practices—*provenance* and *authenticity*—are challenged by the attributes of digital artifacts *qua* objects (Marton 2010). While provenance refers to the documentation of the origins and history of an archived item, authenticity denotes the preservation of the original object rather than the truth or accuracy of its content. A document can be a forgery but still authentic in the sense of providing evidence of actions of an agent (Craig 1992; Factor et al. 2009; Hirtle 2000). The persistency of physical objects, from which these two principles derive, is not given in the digital domain. Dynamic webpages, for instance, draw their content from a variety of sources in order to display up-to-date information for each individual viewing. They are only momentarily rendered into a form that resembles a document. Thus conceived, archival preservation of online material is embedded in a set of conditions established by the attributes of digital artifacts described above (Gladney 2006; Lyman and Kahle 1998; Marcum 2003).

The Internet Archive (www.archive.org) provides a good example of the challenges presented by the archiving of digital artifacts. Since its foundation in 1996, the archive has built a collection of over 150 billion webpages[3] making it one of the biggest databases in the world.[4] Recognized as a library by the State of California, the Internet Archive has provided archived webpages as evidence for lawsuits, thus illustrating the vital role Web archiving already plays in social and economic affairs (Howell 2006).

Given the nature of the Web, the Internet Archive has developed a range of new practices that seek to deal with the inherent fluidity of webpages by "freezing" content at a given time. This is done by taking snapshots of webpages that are automatically selected and harvested by a Web crawler. Snapshots are copies of what is rendered as HTML in a browser including the embedded images, in case the source can be accessed, thus, archiving only part of the distributedness of the original. The same applies to interactivity. Cut off from the wider information landscape to which the original belongs, the snapshot only captures basic HTML

[3]www.archive.org/index.php (accessed July 24, 2012).

[4]www.archive.org/about/faqs.php#8 (accessed July 24, 2012).

functionalities such as text, layout of content, and hyperlinks. More advanced features are not being archived. One can visit a search engine's front page archived in the 1990s but cannot make a search query in the 1990s. The snapshot is thus a partial replication of the respective webpage as it captures the interactivity and distributedness of the original only to a limited extent. In this sense, one has to distinguish between archiving the actual object (authenticity) and its documentation; that is, the creation of documents *about* the actual object (provenance). The practice of taking snapshots results in a combination of the archived object itself and its documentation requiring different approaches to the principles of provenance and authenticity, which we consider below.

Due to the inherent fluidity of the original, the Internet Archive cannot preserve the webpages themselves but only their content as it was displayed in a browser at a given point in time. As a second step, the combination of the original webpage's URL and its file name is used to identify a snapshot. A timestamp, documenting the moment a snapshot was taken, distinguishes the different versions of snapshots of the same webpage. A collection of snapshots frequently taken from the same webpage provides for the documentation of the history of the webpage and, thus, serves the principle of provenance. In other words, snapshots provide for archival provenance, seen simply as the documentation of a webpage over time.

The situation changes in terms of authenticity. Taking the form of snapshots, the preservation of a webpage still results in a digital object. As already stated above, the snapshot is interactive, albeit to a limited extent. A user can still use some basic functionalities such as following hyperlinks to other webpages on the Web or other snapshots held in the archive. A snapshot is also distributed to a limited extent—being an assembly of items such as text and images. Of great concern, however, is the editability and openness of the snapshot, as it can still be manipulated just like the webpage it documents. It requires another layer of software applications to protect the authenticity of the archived webpage for it to be recognized as an actual document that can serve as evidence. However, while second-order technologies, such as security and access rights protocols, prevent the snapshots from being manipulated, the snapshots remain potentially editable and open. By the same token, as technological standards are drifting in ever-shorter periods of time, their updating becomes a periodic yet perennial problem (Gladney 2006; Hirtle 2000). From time to time, the whole archive is required to migrate from one set of technological standards to another, and its potential openness is thus reactivated to make the collection fit into the new standards. Migration inevitably leads to change or even loss of data and, ultimately, to doubts concerning the authenticity of the archive (Russell et al. 1999).

Digital archival documents are not merely collected and preserved but have to be actively created by technological means. This state of affairs results from the instability of the digital artifact *qua* object and signals a departure from traditional practices. The transformation of borderless and steadily changing digital content into a clear-cut and identifiable archival item requires the digital object to be rendered controllable by countering the editability, interactivity, openness, and distributedness the original affords. In other words, the original object can never be archived. The archiving of online items is not a mere copying process of bits and bytes from one server to another but rather a transformation of a digital object into a different kind of digital object that is made to fit the requirements of provenance and authenticity. In light of our argumentation, this transformational process goes beyond the traditional practices of collection, documentation, and preservation, leading not merely to a change of the context in which the object is embedded but to a change of the object itself. In the example we described, the digital object owes its ambivalent ontology to the computational operations by which it is brought to being. What is being archived is not the actual "live" artifact but a transformed version of it that performs as its documentation as well as its partial replication.

The attributes of webpages give rise to new practices of archiving. The instability of digital artifacts *qua* objects is dealt with by (1) the regular taking of snapshots of webpages by creating new digital objects with limited interactivity and distributedness, thus ensuring provenance, (2) recourse to other digital objects such as security protocols controlling for the editability and openness of the snapshot, thus addressing authenticity, and (3) the regular migration of data to up-to-date standards that provide long-term accessibility. These operations suggest that digital objects cannot be archived as such but require continuous archiving and documenting. Being computational operations themselves, archiving and documenting become continuous processes of constructing provenance and authenticity, a condition that marks an important departure from the standard practice of collecting and safeguarding preexisting documents.

These developments are far from limited to archiving. They straightforwardly impact the field of memory institutions (libraries, archives, museums) but they impinge as well upon a much wider and diffuse range of social and information-based practices that depend on the accuracy and reliability of past records (e.g., medicine, law, accounting, and finance). Given the fluidity of digital objects, the notion of cultural

records as persistent reminders and carriers of the past requires reevaluation once they are digitized or born digital. For instance, the perception of memory institutions as knowledge and heritage repositories is inadequate when the artifacts are stored as binary code out of which e-books, digital paintings, or documents are constructed by computational operations that process that code according to changing standards.

Searching the Web

The usefulness of the Web rests to a significant degree on search engines that have taken over the practice of following hyperlinks from one website to another as the dominant solution for navigating online resources (Browne et al. 2007; Dou et al. 2010; Evans 2007; Sen 2005). In this section, we show that search-driven information accessibility and retrieval should be understood not only in terms of the immediate findability of digital artifacts but also in terms of the second-order effects that emerge from reactions to the contingent findability of webpages through search engines. We show below that such second-order effects are crucially tied to the ambivalent ontology of digital objects and can be analyzed using the notions of editability, interactivity, openness, and distributedness.

Search engines are funded by advertising. Their business is generally agnostic to the content of webpages, as long as something useful comes up in the search results to catch consumer attention. The indifference toward content production and preservation conceals, however, important questions concerning the influence search engines have on what is being found. The matter here is not how accurately search engines represent Internet resources, which has already been discussed in numerous studies (Fortunato et al. 2006; Introna and Nissenbaum 2000; Waller 2009). Rather, what is "out there," we suggest, is shaped by the demands a search puts on the online content.

In order to shed light on the relevant mechanisms, let us distinguish between the search engine results page (SERP) and the actual target pages residing on other websites. SERP is the familiar display of search results listed according to their relevance, while the target pages are the digital objects such as webpages and document or image files matching the search query. One might argue that SERP merely provides access to online resources and it can be understood as a simple display of such objects. Such a belief may be reinforced by the fact that the individual instances of SERP are discarded after the user clicks through any of the links provided. Yet, the procedural nature of SERP furnishes the means that mediate our relationship with digital artifacts in nontrivial ways.

Document search has evolved over the last 20 years from an obscure operation preferably left to trained professionals to a crucial cognitive style needed to cope with the exigencies of the everyday business environment. Today, conducting an Internet search is a matter of simple routine, a condition that renders search engines increasingly part of the invisible equipment of everyday life. The utility of a search stems from its straightforwardness and the immense reduction of complexity it affords. Search engines flatten a complex topology of networked contents into an ordered list fitting the user's ongoing task and intentions. Dou et al. (2010) show that the mere display of such a rank-ordered SERP can influence people's perceptions about the relative merits of products, organizations, ideas, etc. Search engine users tend to perceive higher-ranking links more favorably and often settle for items listed on the first page of results, despite the wealth of alternatives just few clicks away on the subsequent result pages (Malaga 2008). Given our increasing dependence on search, these cognitive and behavioral tendencies make it desirable for organizations and even individuals to attain high ranking among search results.

The immediate implications of search engines on information retrieval can be divided into two broad categories. First, scholars have identified a number of potential biases in the search results; there neither is nor can be an inherently right order of things on the Web (Höchstötter and Lewandowski 2009; Introna and Nissenbaum 2000). For instance, it has been argued that search engines index only a fraction of the whole Web, occasionally promote undesirable material, and amplify the popularity of already popular pages as a result of the way their algorithms work (Waller 2009). At the same time, the ordering performed by SERP tends to be taken by the users as *the* order of things for all practical purposes (Introna and Nissenbaum 2000). Second, the potential value of search ranking has created a market for companies offering search engine optimization services for website owners to increase their likelihood of achieving high ranking. A significant amount of research has been conducted to support optimization operations (Dou et al. 2010; Evans 2007; Höchstötter and Lewandowski 2009; Malaga 2008; Sen 2005; Zhang and Dimitroff 2005). Taken together, these two categories cover many important implications of search engines.

The evolving Internet search apparatus and its first-order implications have, nevertheless, turned out to be a moving target for studies based on snapshot evidence and experiments. The ranking algorithms and optimization methods are

in constant flux, rendering some of the details reported in previous studies obsolete. For instance, metadata, which underpins most professional cataloguing practices, is today generally ignored as a ranking criterion by search engine algorithms that attempt to base the ranking on the actual text and other user-visible features of online content in order to avoid being tricked by website owners. Reflexive adjustments between ranking methods and website owners' actions are catalyzed by search engine optimization consultants, who make inferences about secret ranking algorithms and provide suggestions for content producers accordingly. Apart from anecdotal evidence, we have only a vague understanding of the effects that emerge as reactions to the first-order practices burgeoning around digital artifacts.

SERP is an editable, interactive, open, and distributed object that sits between human actors and the digital artifacts they wish to access. Not unlike a library or archival catalogue, the results page both orders and locates knowledge resources, yet it breaks away from stable classifications and the importance of categories as the basis of such order. Instead, SERP is a temporary achievement, contingent upon the interaction between user-specified keywords and a continuously evolving search index. Given the digital constitution of SERP, the access to digital artifacts and their apparent relevance mediated by the search results are not controlled by a single institution but distributed between the search engine companies, content producers, optimization consultants, and advertisers who all influence what counts as a relevant search result in the open anatomy of SERP. The open and distributed nature of SERP is particularly expressed in the manner in which it brings together snippets of target pages across a myriad of organizational and institutional boundaries. Even if the SERP and the matching online resources are served as separate webpages, it is difficult to draw a definitive line between them. The boundary between the SERP and target pages is fluid. If the content of the target pages changes, so does the content of SERP that ultimately turns out to be just a procedure for temporarily assembling other digital artifacts.

The ambivalent ontology of digital artifacts gives rise to interesting, second-order effects in the online environment. Even if a particular artifact can be located by using a search engine today, this may not be the case tomorrow. This instability resonates with the editability of target pages, giving rise to a mutually constituting, reflexive relationship between the means of access and what is being accessed. Digital objects introduce a sort of double instability into information access and retrieval, as both SERP and the target pages constantly adapt to each other. In other words, SERP is highly editable as the ranking of target pages may and often does change. The target pages accessed through searches, on the other hand, are editable as well; their malleability ranges from the laborious editing of PDF documents and images to Wikipedia articles that afford equally the reading and writing of webpages. Technological arrangements such as permanent URLs, version control, and digital rights management systems provide some degree of stability but cannot protect digital artifacts from the contingent findability encroaching on the content accessed through search engines. The inclusion of an online artifact into algorithmic search results is a transient achievement, and the editability of digital artifacts makes it possible to try enhancing this possibility by constantly tweaking the object so that it serves better the search engine algorithms. In turn, the search engine companies adjust their algorithms as a counter-reaction to optimization efforts.

In contrast to traditional forms of document classification (Bowker and Star 1999), the way search engines mediate digital artifacts is not controlled by established professional practices and is inherently unstable (Brown and Duguid 2000). This instability has generated a business opportunity that feeds back into the editable nature of digital artifacts. Unlike cataloguing that attaches metadata to the documents, optimizing online content for search engines subtly but unavoidably shapes the objects we look for. Even if the changes required to make a document rank potentially higher on SERP may be relatively small, they introduce a new and cumulative source of variation that makes, for instance, the preservation of digital objects more difficult. As we have discussed in the previous section, archiving requires freezing the digital object, while maintaining its findability provokes constant rewriting.

Discussion

The study of the Internet Archive and the content dynamics unleashed by search engines demonstrates that digital objects are embedded in shifting interdependencies with other entities in larger digital ecosystems. Indeed, both case illustrations suggest that artifacts of this sort are no more than software procedures by means of which they are assembled to proxies of objects, only to be unpacked, edited, reprogrammed, and reassembled. Digital artifacts *qua* objects lack the inherent bounds and durability granted by physical underpinnings and traditional media. In this respect, the framework of ideas we present provides the means for approaching the operations (editability, interactivity, reprogrammability) by which digital objects are assembled, the ecology of relations (distributedness, openness) within which these operations are embedded, and the implications these have for managing documents, knowledge, and, ultimately, knowing. The case of the Internet Archive helped identify new practices of documenting and

Table 2. The Implications of the Four Attributes of Digital Artifacts for Archival Snapshots and SERP

	Archival snapshot	SERP (and its target pages)
Editability	Easily editable content needs to be controlled by second-order technologies to produce stable archival objects	Website content producers edit target pages to make them fit better with search algorithms
Interactivity	Interactive features can be archived only to a limited extent leading to partial replications of the original item	SERP is rendered interactively according to the user-supplied keywords and a constantly changing search index
Reprogrammability/ Openness	Reprogrammability/Openness is controlled by second-order technologies but becomes re-activated when the database is migrated	The rank-order and content displayed by SERP depends on the constantly changing content of target pages
Distributedness	The distributedness of the original item is archived to a limited degree, since the snapshot is necessarily cut off from its active links to external sources	SERP is a contingent assembly of content snippets from other online resources

creating digital objects, while the example of search engines disclosed the second-order effects that arise from the content practices with which search engines are associated. Table 2 summarizes and compares the different implications the four attributes of digital objects have in these two contexts.

In more detail, the Internet Archive illustrates that the category of the document, a pillar of the practice of archiving and widespread social convention, is no longer a clear-cut and evident object of social and information-based practices. Webpages are selected and stabilized by means of unobtrusive, technologically driven processes with the view of rendering them identifiable as objects of archiving. Despite the static appearance, an archival snapshot remains a computational operation sustained by respective software and hardware configurations. In a sense, it is more appropriate to refer to the archived snapshot as *documenting* rather than as a document. The drift of technological standards results in inevitable changes to the archival computer system—changes that need to be documented as well. Documenting itself needs to be continuously documented and archived, as the underlying technological standards become obsolete and computational platforms change over time. The principles of provenance and authenticity are thus computationally processed and sustained, taking the reflexive forms of documenting the documentation and, ultimately, archiving the archive. The archival principles of provenance and authenticity are redefined to fit the operative exigencies in which digital objects are embedded.

Some of these issues are further reinforced while new ones emerge as Internet search engines become the primary mechanism for identifying documents and information in the online environment. By shifting away from stable categorizations embedded in the professional practices of memory organizations (e.g., libraries, archives, museums) and other institutional fields (e.g., medicine, accounting, law), the ranking of the results page promotes a formal and context-free logic of search that makes the findability of digital artifacts a driving force in the development of content (Morville 2005). This is a powerful and even liberating condition in terms of access to information. At the same time, indexing dictated by global accessibility tends to cut objects off from context-specific knowledge and knowing (Boast et al. 2007). Furthermore, search engines provide an inherently unstable form of mediation when compared to traditional cataloguing practices. Not only are the search results unstable but their instability is reflected onto digital artifacts and, in turn, back to search algorithms. The reflexive adjustments between SERP and the digital content can be seen as a partial disembedding of content production from local settings and a transition to another generic context, marked by the interplay between the global search engines and search engine optimization efforts. Online resources are not simply made findable by virtue of innovation in search engine technology. Rather, they are shaped under conditions dominated by search engines and the findability practices and techniques they disseminate.

Table 3 further summarizes and compares the case illustrations. Placed in a broader purview, the practices that arise with respect to digital archiving and searching can be seen as endpoints of a continuum. While the former perceives the fluidity of digital objects as a problem that requires counter mechanisms or taming, the latter flourishes due to the ever-shifting information environment it helps to navigate and the digital objects found and constructed along the way. Other contexts of practice and management could be positioned on the continuum between these two endpoints.

Table 3. The Implications of Digital Artifacts Illustrated in the Case of the Internet Archive and Search Engines

	The Internet Archive	Search Engines
Problem	How to archive digital artifacts	How to find digital artifacts
The ambivalent ontology of digital objects	• Challenges established notions of provenance and authenticity of evidence • Necessitates the technological maintenance of the long-term accessibility of the archive	• Breaks away from stable, professional classifications as the basis of access to content • Enables the creation of a rank-order to signify the relevance of entities in real time
New social practices	• The archive takes recurrent snapshots to provide provenance • In order to ensure authenticity, several second-order technologies are implemented • The data is repeatedly migrated to sustain its accessibility over time	• The reflexive optimization of online content and search algorithms creates a new collective domain of activity • Agents react to the contingent findability of digital objects giving rise to second-order effects

Given the centrality of documents, documenting, and their retrieval in most organizational settings, the structures fashioned by digital objects represent conditions that may be difficult to ignore. The mutability of digital objects contradicts the assumption that, once knowledge is made explicit and codified into a medium, it can remain unchanged (see Kane and Alavi 2008). Our findings suggest that the value and appropriate control of digital artifacts often derives from coping with how they change. For instance, a personal profile on a social networking site or corporate repository must constantly change to reflect its owner's identity and shifting commitments and connections with other, similarly fluid entities in order to remain functional. The value of the profile is tied to its constant change and the steady connectedness it maintains to other changing entities. Generally, attempts to manage knowledge by codifying (Alavi and Leidner 2001; Hansen et al. 1999) it into digital repositories have to deal with the difficult problems of archiving and making digital objects findable and accessible, in one way or another. The two case illustrations should thus be seen as extreme instances of issues that extend beyond the boundaries of archiving and digital search, as other relevant research testifies (Ekbia 2009; Manovich 2001; Yoo et al. 2010).

Both examples provide a further illustration of the complex idea of the *self-referential* (Kallinikos 2006; Marton 2009; Yoo et al. 2010) or *reflexive* (Hanseth and Ciborra 2007) dynamics through which digital artifacts *qua* objects come to exist and develop. Digital objects can only be accessed, assembled and acted upon by other digital objects. Accordingly, the introduction of digital objects into domains of social practice usually begets other digital objects, as a means of stabilizing, identifying, locating or manipulating extant digital objects. The Internet Archive is itself a reaction to the digital complexity and fragmentation of the Web in which it participates and further aggravates by creating more digital objects (webpage snapshots) for the sake of preserving others. In the case of Internet search, the malleability of webpages allows website producers to tailor content for SERP, which then adapts to new tactics, necessitating even more content tailoring. Search engines help to resolve the problem of information affluence (too many webpages) by paradoxically adding new information (by creating a rank-ordered SERP) that then becomes a driver to further content production, requiring further adjustments to the algorithms underpinning SERP.

Implications for IS Research and Practice

Two major blocks of ideas emerge from the themes we have pursued in this paper. First, contemporary digital artifacts lack the stability and plenitude of traditional objects that are tightly coupled with their underlying media such as paper-based documents. They are constantly in the making. Second, digital artifacts are embedded into webs of technical and organizational relations that further reinforce their instability and ambivalent ontology. Digital objects, we claimed, presuppose and steadily beget other digital objects, often distributed across settings. These fundamental conditions are implicated in the formation of larger digital ecosystems that never settle, as the artifacts by which they are made undergo steady change and the architecture of technical and organizational relations to which they belong shift.

Taken together, these changes converge to fundamental transformations in the development and use of digital artifacts. A paradigm shift is underway in which *relations* and *change*

trajectories (rather than single or locally embedded families of artifacts and recurrent or robust functionalities) emerge as major issues of IS management. The case illustrations presented in this article provide evidence in support of these claims. Confronting digital artifacts and systems of this kind asks for the apprehension of the complex ecology to which they belong and its inherent dynamics (Kallinikos and Mariategui 2011). It also requires proactive contemplation of relations yet to come and, by consequence, built-in capacity of such systems and artifacts for steady adaptation and functionality enhancement or mutation. These trends have, no doubt, been observed in the literature. A battery of terms such as flexible standards (Hanseth and Lyytinen 2010), function-agnostic interfaces (Yoo et al. 2010), intentionally incomplete technologies (Garud et al. 2008; Zittrain 2008), and the tradeoffs between core and peripheral elements in platform management (Baldwin and Woodard 2009; Tiwana et al. 2010) are indicative of different aspects of the changes we pinpoint. However, and despite the rising awareness among IS researchers, these issues are as yet little studied and even less well understood. Information systems practice and research are on the verge of a major shift. A new breed of ontologically ambivalent artifacts is developing adjacent to the static and self-sufficient population of objects and technologies that have hitherto been assumed to prevail in IS practice and research.

The far-reaching technical, behavioral, and organizational implications of these trends are better apprehended against the historic importance that stable objects have assumed in the making of cause–effect or means–ends relationships, on the basis of which actions can be planned, carried out, and evaluated (Beniger 1986; March and Olsen 1976, 1989). Recurrent outcomes, produced by stable objects and practices, are essential to the construction of manageable social orders. They provide the indispensable means for comparing and evaluating activities within and across contexts, and for building accountable organizational roles and courses of action (Kallinikos 2006). The dynamic character of digital objects, the fluid nature of digital content, and the shifting architecture of relations into which they are embedded challenge these paramount principles; they put a premium on drift rather than stability and control, change and flexibility management rather than accountability, while valorizing expression rather than restraint. The literature review and the case illustrations indicate these to be extremely important issues.

While joining hand with a wider stream of IS research on larger digital ecosystems (e.g., Ciborra 2000; Edwards et al. 2009; Hanseth and Lyytinen 2010; Tilson et al. 2010; Tiwana et al. 2010; Yoo et al. 2010), the focus on digital artifacts *qua* objects, as opposed to IT platforms or infrastructures, directs attention to behavioral issues occurring at the intersection of structural and technical factors with social practices (Kane and Alavi 2008). However complex or unruly an object may happen to be, it is an accompaniment to human action in ways that large systems seldom are. Digital objects certainly admit investigation in terms of the technical and organizational requirements that ensure their interoperability and growth. Still, the conceptualization of digital artifacts and operations as objects singles out the intersection between technology and human practices as the appropriate level of analysis. In other words, digital objects entail a closer focus on practices and digital content dynamics than standards or design and governance of digital ecosystems (Tiwana et al. 2010). Such focus enables investigating how collective rationalities (e.g., archiving mutable objects; finding, creating, and displaying content on the Web) are tied to or accommodated by the key attributes of digital objects (editability, interactivity, openness, distributedness) recurring at the intersection with social practices. These attributes are essential in understanding the nature of the interlocking of individual or collective pursuits with larger ecosystems, far beyond the case illustrations we provided in this article. Wikipedia, YouTube, and Facebook provide notable examples that show how individual or collective pursuits are tied to platforms or ecosystems in ways that feature interdependent yet small episodes, granular contributions, and shifting commitments, in short, characteristics that can be approached by recourse to the conceptual tools digital objects offer (Aaltonen and Kallinikos 2013).

The middle ground between technical and behavioral issues digital artifacts *qua* objects occupy calls for distinguishing our focus from the recent *sociomateriality* approach (Orlikowski 2007, 2010; Orlikowski and Scott 2008). While recognizing the poignancy of the concerns raised by Orlikowksi and her colleagues, the ideas we put forward question the understanding of technology as solely a process of situated enactment or interpretation, and the empirical investigation of bounded local contexts as the primary loci of socio-material entanglements. Allowing fine-grained human interventions along the lines analyzed above, the ontology of digital artifacts is nonetheless not a local affair, whereby human agents interpret, act upon, or otherwise perform technologies. It is rather the outcome of wider and time-ridden developments that construct not simply local contexts but also forms of agency, in the sense of implicated user models, mechanisms of attention sampling, and skill building and diffusion (Lamb and Kling 2003; Pollock and Williams 2008). Technology and humans are surely not exogenous to one another (Orlikowski 2007), yet their interpenetration is not a local resolution, other than in a limited sense. Our focus on the intersection of technology and social practice thus transcends agency-centric explanations of social and organizational

arrangements. The ontology of digital objects helps single out those recurrent, structural attributes through which local resolutions occur thanks to the capabilities technologies embody and mediate (Leonardi et al. 2012).

The implications of the ideas we put forward extend beyond the themes we have outlined in this paper and concern a wider range of problems within information systems (e.g., Yoo et al. 2010) but also beyond it (Varian 2010; Zittrain 2008). If the shape of the change is of the degree we claim, then the implications of our ideas touch upon IS fields as different as systems development and business process design, IT strategy, IT-driven innovation, or e-government. All of these fields must, in one way or another, confront the cardinal issues of current versus future use, adaptation versus adaptability, and local adequacy versus ecosystem dependence (Aaltonen and Kallinikos 2013; Garud et al. 2008). The relevance of our ideas further extends to the dynamics of content and information management in the digital ecosystem (Kallinikos 2006). The relative independence of digital content production and availability from the underlying hardware or software infrastructures and the separation of applications from devices (Yoo et al. 2010) are major field developments that feature core attributes of digital objects (e.g., reflexive dynamics, perpetual editability). The study of digital content dynamics still awaits research, despite some interest, often narrowly technical, speared by the fads of business analytics and "big data." The implications of our ideas even touch upon issues of research design and methodology. Given the interconnected and distributed nature of digital artifacts, it would seem relevant to contemplate the degree to which case studies of bounded contexts can remain a suitable research design and the study of situated actors the sole loci of data collection and analysis. If taken seriously, the ambivalent ontology of digital objects offers excellent opportunities and incentives to rethink empirical research and the phenomena studied by the IS community.

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