Designing digital artifacts as transient assemblies with different digital materialities

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ABSTRACT

This paper is inspired by the concept of digital metamaterials and advances a proposal for a genre of digital artifacts that exhibit the transformative capacity to transcend technical boundaries in digital ecosystems. In terms of theoretical footing, our approach is ground on the conception of 'software as material' with intrinsic properties such as *interactivity*, *editability*, *openness* and *reprogrammability*, *distributedness* and *emergence*. We claim that as these properties are purposefully inscribed into digital artifacts, the latter become transient assemblies capable of exhibiting different digital materialities. To illustrate the concepts, the paper reflects upon a case study featuring the use of digital composites in boundary spanning virtual collaboration in organic farming.

Categories and Subject Descriptors

D.2.2 [Software Engineering]: Design Tools and Techniques - H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces

General Terms

Design, Human Factors.

Keywords

Digital materiality, Assemblages, Calendars, Digital traces.

1. INTRODUCTION

Although material concerns in computer-mediated settings are not immediately obvious [1], they are increasingly debated by IT designers, management theorists and information systems (IS) researchers. Designers tend to focus on the *form-giving materials* such as sketches, prototypes and models that enable the instantiation of a concept or an idea [2][3]. Management scientists assess the *material effects* of digital technologies in the distributed organizing of work [1][4]. Information systems researchers tend to emphasize the *material constitution* of IT in terms of properties of digital artifacts [5]. As these views are not necessarily compatible or comparable, there is a compelling need to untangle intrinsic properties that determine the information processing capacity of digital artifacts.

The present research is inspired by (some distinct properties of) digital metamaterials [6] and advances a proposal for a genre of digital artifacts that embody the capacity to be mobilized across contexts (i.e., physical vs. computer-mediated) and digital settings (i.e., local data stores, platforms, clouds, etc.) so as to be transient assembly of resources resident across potentially different digital materials. We approach the concept from the perspective of Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW) with an explicit focus on the design-oriented concerns that underpin the materiality of digital ecologies. Following [7], we understand digital ecologies as "… systems consisting of different digital and physical artifacts, people, their work practices and values", placing particular emphasis on "… the role artifacts play in embodiment, work coordination and supporting remote awareness". The rest of the paper is structured as follows. The next section reviews the constructs of digital materials and materiality, anchoring them to the relevant scholarships. Then, we briefly discuss digital composites by drawing parallels with recent advances in science and engineering [6]. The concept is illustrated using a case study in which coordination and awareness activities between peers of an organic farming digital ecosystem are approached from a material perspective. The paper is concluded with a critical discussion, implications and promising areas of future work.

2. BACKGROUND AND MOTIVATION

2.1 Materialities and digital materials

Leonardi [1] defines "materiality" as the practical "instantiation of theoretical ideas" and concludes that digital artifacts possess digital materiality which determines the process of organizing. Such digital materiality is acquired by purposeful implication of digital materials which are designed to exhibit certain affordances. But what exactly may be considered as digital material?

Scholarship indicates that digital materials may range from programming languages [3], tools for crafting digital artifacts [2], services that mashup content [8], infrastructures (i.e., grids, clouds, etc.) that retain digital artifacts and facilitate their appropriation [9][10] to virtual settlements which enable cyber-formations such as online communities to flourish [11]. Recent works claim that digital materials may also be combined to craft

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composite constructions with ‘unconventional’ affordances such as sensing or self-enacting functions [12]. Assuming that all the above are valid connotations of digital material, it stands to argue that digital materiality should be understood not only in relation to the ‘matter’ (i.e., computational device, light, texture, etc.) from which certain digital artifacts are constituted, but also in relation to the settings within which these artifacts reside, are experienced and enacted. Arguably, this lens is broad enough to cover materialities related to specific genres of software but also social accomplishments such as online teams, virtual alliances and digital communities enacted in cyberspace.

In HCI and CSCW which constitute the conceptual frames of the present research, material thinking can be traced in at least three distinct streams of research. Firstly, HCI designers are accustomed to working with various form-giving materials such as sketches, images, models and prototypes [2] or programming languages [3] to instantiate ideas and concepts as material outcomes of the design process. Noticeably, the type of materiality of these outcomes is relative and determined by the materiality of the process through which they are produced. Thus, prototypes of the same concept may be instantiated by totally different design processes and perceived in relation to different materials. As a result, their digital materiality may vary. For instance, computer-mediated communication may be instantiated as exchanges of textual messages in a chat room, 2D/3D visualization or as co-engagement in a teleconferencing session. From this perspective digital materiality – a characteristic property of the process – and digital materials – the outcome of the process – are not identical constructs and do not raise similar concerns.

Another stream of HCI research has explored material foundations of enacted artifacts and cyber-formations. Early work on the theory of virtual settlements [11] anchored pre-requisites of computer-mediated spaces that determine certain outcomes such as virtual communities. More recent research confirms that digital settings such as the micro-blogging platform Twitter [13][14] or video-sharing services [15] can be regarded as virtual settlements, thus enacted virtual communities may be established as a result of different digital materialities.

Materiality has also been grounded on the media used in design processes [4]. For instance, computational composites [12] represent a category of artifacts which cannot be fully understood in terms of a single medium, since they are characterized by the synergistic co-presence of physical and digital media. Contrasting digital composites to the earlier cases of artifacts such as sketches and prototypes (for instantiating ideas) or virtual communities (for enacted social accomplishments), it may be argued that whereas the latter are the result of certain materiality, the former assume (concurrently) multiple materialities co-embedded and fused in the same construction.

These works point to the conclusion that digital artifacts exhibit digital materialities which are determined by the presence or absence of certain properties of the underlying materials from which they are composed. Moreover, as each genre of material possesses its own properties (i.e., texture, light, gravity, computation, etc.), it is of paramount importance to assess the new forms of digital materialities enabled by synergistic use of materials with different properties.

2.2 Material properties of digital artifacts

Since our primary concern is set of digital artifacts that rely on software, current interest is focused on the properties of software that constitutes not only the material which invokes social agency (either individual or collective) but also the medium through which material concerns are manifested, become tangible and sensible. In this vein, attempts to qualify the properties of software that distinguish it from physical materials provide a useful baseline. Kallinikos et al. [5] conceive digital artifacts as embodying *interactivity*, *editability*, *openness* and *reprogrammability*, *distributedness*, *modularity* and *granularity*. The first four properties are particularly relevant. Firstly, digital artifacts are *interactive*, thus offering alternative pathways along which human and non-human agents can activate embedded functions, or explore the arrangements of information items underlying it. Secondly, digital artifacts exhibit *editability* which is achieved by rearranging the elements by which a digital object is composed, by deleting existing or adding new elements or even by modifying some of the functions of individual elements. Thirdly, digital objects are *open* and *reprogrammable* in the sense of being accessible and modifiable by a program (a digital object) other than the one governing their own behavior. Finally, as the outcome of interoperability and openness, digital artifacts are seldom fully and entirely understood within a single source or institution. This makes them *distributed* assemblages of functions, information items or components spread over information infrastructures and the Internet.

2.3 Research objectives and contributions

The efforts briefly reviewed above indicate that digital artifacts and their material analysis raise several implications for the design community. Clearly, there is a compelling need for a better understanding of materials and their properties, but also new processes for fabricating and crafting novel digital experiences. Such insight would contribute, amongst other things, to establishing a frame of reference to guide HCI design towards a material turn. Although, the need for such a turn has been widely proclaimed and justified [16], it is still far from being consolidated and detailed. In an effort to fill this gap, the present work builds on established perspectives and steps further by drawing parallels with digital metamaterials as conceived in materials science and engineering [6].

3. DIGITAL COMPOSITES

In material science and engineering [6], digital metamaterials are artificial structures that are engineered to exhibit unusual properties that stem from the sum of their parts, instead of the parts themselves. In the field of HCI and the design of user experience, digital metamaterials may be used as a lens for scaffolding a genre of digital artifacts anchored by two key properties – on the one hand, they are constituted as transient assemblies of resources distributed across different digital materials, while on the other hand, they may themselves constitute a digital material for other digital artifacts. The resulting effect is a category of computational compositions with their own aggregate processing, which at least in part, may be delegated to and determined by the properties of the digital materials that constitute the composite artifact. A distinct feature of such composites is that their processing capacity is emergent and continuously in flux, since it is partly determined (even temporarily) by the state of affairs of their parts.

Although there are no pre-conceptions about the functional purpose of composite digital artifacts, it is possible to envision an architectural pattern (see Figure 1) general enough to model a variety of encounters, including but not limited to the genre commonly referred to as mashups. It is worth noticing that the category of digital artifacts envisioned may be intended for human use but also non-human appropriation, as briefly explained below. In other words, they possess their material agency designating a capacity to process and manipulate data without any human intervention. Being composites, they should also operate on the basis of contracts which are independent of how their parts exercise their performative capacity. Consequently, even totally different digital materials can be configured (purposefully) so as to act interdependently, thus constituting meaningful compositions of digital artifacts. Nevertheless, such configuration should not be ad hoc.

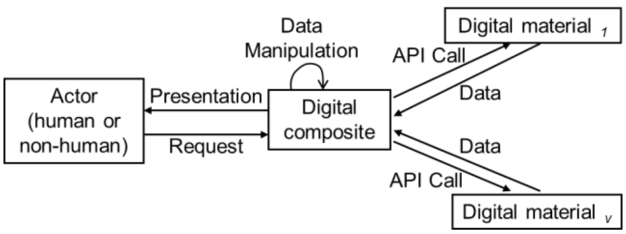

Figure 1. Architectural tactic for digital composites

In addition to the basic properties of digital artifacts defined in [5], digital composites of the sort considered in the present work are characterized by three defining features which collectively qualify the construct of *emergence*. The first defining feature is that composite digital artifacts are in continuous flux, thus in need to 'reveal' internal processing while in operation. Phrased differently, since they are stable only temporarily, they should exhibit a capacity for digital trace data management so as to anchor internal performativity which is typically invisible and immaterial. The second feature is that digital composites can in themselves operate as constituent material of other digital artifacts (in a digital ecology). Consequently and in contrast to applications that mashup data form various sources, digital composites need not be appropriated only by human actors. They can also be invoked by non-human actors, including software/services, IoT devices, etc. To this effect, they should provide a contract or protocol, such as an Application Programming Interface (API) for receiving and responding to requests by actors. The last defining property of digital composites is their transformative capacity. This is a relative construct, incapable of absolute or quantitative measurement. It can only be determined by intrinsic properties of the digital materials that compose the digital artifact and the new human intentionalities invoked. For instance, the Twitter micro-blogging service transforms the meaning potential of a typographic convention, the hashtag, so as to upscale the call to affiliate with values expressed in tweets as well as to render language searchable. Twitter data can be further processed and transformed to depict enacted social accomplishments such as imagined communities [14] or ambient affiliation [13].

4. CASE STUDY AND REFLECTIONS

In recent R&D work, we have attempted to explore the notion of digital composites in a specific setting that entails the re-alignment of organic farming using computer-resilient media [17][18]. Organic farming is an agricultural system that involves multiple parties in different roles aiming to provide consumers with fresh, tasty and authentic food while respecting natural life-cycle systems. Such a system relies on shared objectives, common principles and dedicated practices to minimize the human impact on the environment, while ensuring quality in process and products. Our current effort is grounded on treating established digital technologies, including dedicated systems such as crop profiling mechanisms, digital maps, community building software and file sharing services, as digital materials whose re-configuration leads to emergent transient assemblies of distributed digital resources. Phrased differently, we are keen to address what digital composites may be crafted using the aforementioned digital materials and how digital materiality of digital composites may be anchored to properties such as *interactivity*, *editability*, *openness* and *reprogrammability*, *distributedness* as well as *emergence*.

4.1 Envisioning digital materials

Scenario envisioning and breakdown analysis were recruited as analytical instruments for assessing appropriate digital materials. Figure 2 depicts a general template for crafting scenarios in organic farming. For illustration purposes, let us consider an organic farmer affiliated with a cooperative (A) who is cultivating a specific crop (R) such as organic tomatoes in a designated farmland (R) during a certain period. The commitment to certain organic principles (X) entails the undertaking of specific obligatory activities (R), as well as optional activities (R) of high added value for the final product. It is therefore important for organic farmers to plan activities, record their interim and final outcomes and provide suitable justification regarding their material setting, including tools used, composts, fertilizers, etc. Such activity logs are often reviewed – both during and after cultivation – by inspectors of certification bodies (A), domain experts (A) as well as the farmers themselves (A). For instance inspectors may use this evidence to assess quality attributes and certify production. Domain experts or farmers may also explore the state of progress or compile evidence for future improvements. In conventional settings, most of the activities outlined above are based on intuition and invoke human operations in the field, record-keeping in paper-based farming books and in some cases exchange of digital documents. As a result, activities lack the digital materiality that would promote their transparency and accountability. If however, these activities were re-aligned so as to obtain digital footprints across potentially different digital settings (DS), we would be able to reason about not only their transparency and accountability, but also about emergent social ties and togetherness (T). Nonetheless, this would necessitate a focus on digital materials (DS) facilitating virtual presence, user roles, crop and cultivation profiling, registration of farmlands, shared content management, coordination and awareness, etc.

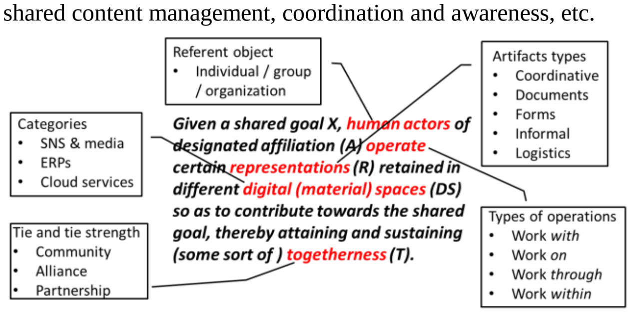

Figure 2. Scenario template

Following assessment of technical offerings and iterative prototyping our analysis coined several genres of software as being relevant digital materials. Specifically, the Liferay enterprise portal was chosen for partner registration, role assignment and crop profile management. Popular file sharing services such as Google Drive, Flickr and YouTube would provide hosts for shared digital resources, while mapping services (i.e., Leaflet & HERE maps) could facilitate farmland management. Communication and informal exchanges could be serviced by argumentation platforms such as Disqus but also by other asynchronous and synchronous technologies. In addition, the Asana service for managing shared tasks was deemed as appropriate. The question which is now posed is what kind of digital composites may be crafted, given the above choices.

4.2 Crafting digital composites

As showcase of a digital composite, we will briefly address the digital equivalent of the 'farming book'. At core, the 'farming book' is a reconfigured calendaring service which is extended to act interdependently with the digital services outlined earlier, but also with other digital artifacts such as a domain-specific search engine [18]. As discussed below, its distinctive features qualify it as a transient assembly of resources distributed across different digital materials and assembled dynamically.

4.2.1 Interactivity

The calendar was designed as an extension of Google Calendar so as to operate in a portlet of the Liferay CMS. In its current version, it is tailored to the domain of practice being described and exhibits the *interactivity* depicted in Figure 3. Once a specific farmland is selected (top left hand side), the calendar assembles the relevant activities and renders them as 'scented' calendar events. As shown, visual scent is recruited to qualify the represented activities in terms of type (i.e., mandatory versus optional), state (i.e., completed or pending) and designated quality benchmark of voluntary certification scheme.

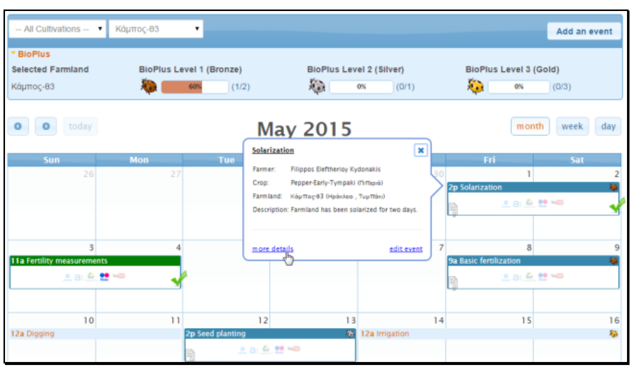

Figure 3. An instance of the farming book

For example, Figure 3 depicts three mandatory activities colored blue (i.e. 'Solarization', 'Basic fertilization' and 'Seed planning') and one optional / voluntary activity (i.e., 'Fertility measurements). In terms of state, the green check mark on the bottom right corner of the events 'Solarization' and 'Fertility measurements' signifies that the respective activities have been completed. Otherwise an activity is pending. As for quality benchmarks, the 'ladybug' icons on the top right corner of events such as 'Solarization' and 'Seed planting' qualify the respective activities in terms of the benchmarks of a Bioplus-like voluntary certification scheme. Such a scheme entails three quality benchmarks, namely 'Bronze', 'Silver' and 'Gold' (see section above the calendar) which are constituted by designated achievements. As farming proceeds and activities become completed, the state of practice in the current cultivation can be assessed in relation the three benchmarks, thus anchoring achievements so far and pending tasks with respect to a designated benchmark. In addition to the custom filtering mechanism (i.e. cultivation or farmland selection) and the basic calendar navigating actions (i.e. different views, previous/next buttons etc.) the user is able to interact with each event explicitly.

4.2.2 Editability (by human and non-human actors)

The calendar is *editable* in two different modes which can be qualified in terms of the actor initiating the edit function. The first mode entails edits by the calendar owner (human user) to schedule new events or modify scheduled events. Both these are facilitated by conventional means such as the 'Add an event' button or the links in the event's dialog in Figure 3. The second mode involves operations initiated by non-human actors i.e., software components or services that maintain shared access to the contents of the calendar. This type of editability is a direct consequence of the imbrication tactic [9] that characterizes the development of the calendar. To illustrate this form of editability by non-human actors, it is worth considering briefly how calendar events are created automatically from crop profiles. A crop profile is an abstract specification of the activities to be followed during an organic cultivation. Typically, they are assembled by certification bodies so as to comply with designated objectives and best practices. Variations in the crop profile are possible to accommodate location-specific conditions or custom practices. In the case of our organic alliance, crop profiles are assembled by dedicated software which codifies them as sharable resource in a file sharing service such as Google Drive. As such they can be further processed and articulated as needed. Figure 4 presents a timeline of the crop profile assigned to the farmland represented in Figure 3.

Figure 4. The crop profile of the farmland in the calendar

The top timeline outlines the abstract crop profile as imposed by national authorities and adopted by a certification institution. The timeline below is the tailored version of the crop profile which is used in the specific farmland to accommodate location-specific requirements. Tailoring is useful as it allows farmers to achieve product differentiation based on quality targets (i.e., adoption of a voluntary certification scheme) or take care of seasonal and / or situational specificities. For instance, in Figure 4, the activity 'Solarization' is reduced while an alert has also been introduced in the tailored plan. Once, crop profiles are tailored (if and as needed) they are mapped into calendar events. Thus, the 'Seed planting' event in Figure 3 stands for the corresponding tailored instance of the activity designated in the crop profile in Figure 4. Consequently, the calendar as digital artifact exhibits editability by non-human actors (i.e., crop profile management software) which transform indexical representation of crop profiles into calendar events.

4.2.3 Openness and reprogrammability

The capacity for editability by non-human actors, briefly reviewed above, proclaims the artifact's capacity to be *open* and *reprogrammable*. In the case of our calendar, such openness and reprogrammability are facilitated by a dedicated Application Programming Interface (API) designed to provide a set of appropriate calls not only for retrieving information about (all or selected range of) calendar events but also creating new ones. As an example, Figure 5 depicts the API calls to create calendar events, such as 'Fertility measurements' and 'Basic fertilization' depicted in Figure 3.

Figure 5. API call for creating events

It is worth noticing how these inscriptions designate variations in the interactive manifestation of the respected events in Figure 3. Specifically, the API call for the event 'fertility measurements' (Figure 5, left) represents an optional activity in state 'confirmed' but not part of the voluntary certification scheme. As a result, the respective event in the calendar carries the designated visual scent but no indication of quality benchmark. On the other hand, the API call for 'Basic fertilization' (Figure 5, right) represents an activity that is part of the voluntary certification (thus the designated quality benchmark) and whose state is 'tentative' (no check mark).

4.2.4 Distributedness

Distributedness of the calendar is best illustrated by briefly describing a possible chain of activities that anchor the digital materiality of the event 'Fertility measurements'. As evidenced from Figure 3, this event has been 'confirmed' by the user, while it possesses digital traces in Flickr.

Figure 6. Depositing digital evidence of farming activities

One possibility for reaching this state of affairs is depicted in Figure 6 where the farmer makes use of a tablet to alter the event's state (from 'tentative' to 'confirmed') and deposit evidence (for such change) which is a Flickr photo. It is worth noticing that this time the event in the calendar is mobilized as a transient assembly that spans boundaries and manifests itself in a different material context, namely that of the tablet, to invoke remote human action in response to a physical activity in the field. Taking into account that the same result may be achieved by direct manipulation of the calendar in Figure 3 (or indeed other viable means), it stands to argue that distributedness entails not only the distribution of activities across physical locations and material settings, but also the distribution of the digital evidence standing for these activities across services.

4.2.5 Emergence

The final property of the 'farming book' relates to its emergence that stems from the fact that it is continuously in flux as it is enacted not only be humans but also non-human actors. Figure 7 depicts the digital traces of the event 'Fertility measurements' as retained across services (i.e., Google Drive, Flickr and YouTube). Resource cross-referencing is achieved by virtual referents which however hide the intrinsic details (i.e., storage, resource meta-data and semantics) bundled in each service. Clearly, as these digital traces are physically retained and managed by different hosts, they embody emergent digital materialities. For instance, resources may be tagged differently in each separate service. Thus, up-scaling such service-intrinsic properties and making them accountable through the 'farming book' is not only possible and useful as described in [18], but also anchors events as transient assemblies of resources.

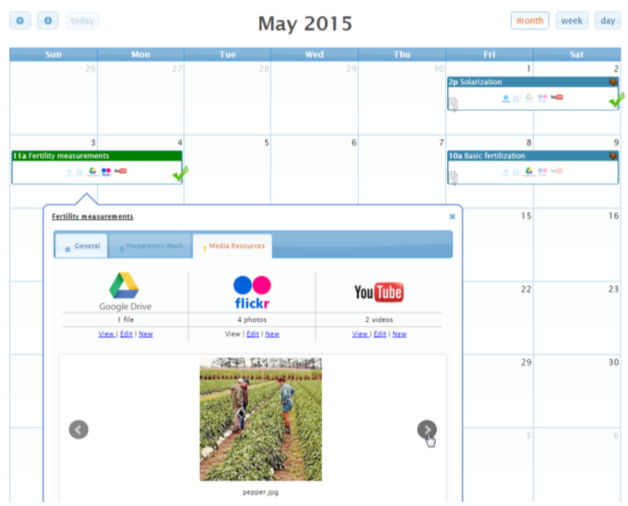

Figure 7. Evidence of an event's digital materiality

In addition to emergence as related to resources, the 'farming book' is designed to exhibit emergent features which allow it to be recruited as digital material in its own right. Specifically, events in the 'farming book' are bundled with meta-data such as user specific meta-tags [18] or domain-specific inscription of codes and categories. Such meta-data render the 'farming book' a searchable digital repository. An example is illustrated in Figure 8 where the 'farming book' is invoked by another digital artifact, namely a search mechanism using the tag 'bioPlus'. As shown, the result returns an emergent collection of events qualified by this tag. Moreover, subsequent search refinements could bundle together resources assigned to these events even though these resources may have never been tagged as 'bioPlus' in their native hosts. Noticeably, these results would not be viable with other search engines, either general-purpose or service-specific. Consequently, the farming book serves an additional function, that of establishing a digital constituent of another digital artifact, namely the search mechanism.

Figure 8. The 'farming book' as searchable repository

5. SUMMARY AND CONCLUSION

The present research has shown that by re-aligning and re-configuring designated digital materials, calendars are transformed from mere coordination artifacts to a transient assembly of resources and a digital composite capable of operating interdependently with constituent materials but also other digital artifacts. This capability rests on two premises, namely: (a) recognizing key properties of digital artifacts that determine how they are created, mobilized and experienced across boundaries (both physical and digital); and (b) adopting a material turn in designing transient digital assemblies with traceable digital materialities. With respect to the former, our example confirms that inscriptions for designated properties lead to crafting malleable digital artifacts with an embedded boundary spanning capacity that allows them to be invoked by different actors and across material settings and devices. As for the latter, our reference case illustrates the results of reconfiguring primitive materials such as online calendaring, Liferay portlets and various file sharing services to craft the 'farming book' as a transient assembly of bundled digital resources distributed across digital spaces. The above provide a step in the direction of designing collaborative digital ecologies by realigning (previously) separate digital materials in ways that mix their digital materialities and establish emergent assemblages between human and non-human actors.

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