Sustainability APIs:
Situated Affordances for the Material World

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On the underside of convenient shopping, shiny consumer devices, and new experiences in interactive media, a mostly unobserved accretion of trash and pollution continues. It would be a tremendous achievement to wrangle these post-consumer resources for our own desires. This paper is a contribution to this effort.

The goal of this paper is to examine the design of interfaces to physical goods that grant them the proper affordances for participating in cradle-to-cradle production cycles. One of the central challenges is to clearly communicate how products can continue to serve their roles in such cycles even during their tenures as consumer and post-consumer goods, at which time their connection to such cycles has been poorly expressed, while maintaining the freedoms and flexibilities of decentralized production. Our strategy for such communication is to ambiently situate the product with its role, by juxtaposing the product with scenarios of its future possibilities, helping to adjust usage behavior by better articulating possible values.

First, we will review the various unsituated externalities that such interfaces might counteract. Next, we will examine why application programming interfaces (APIs) are an appropriate early-stage design deliverable. After this, we will look at the immediate predecessors for our interfaces. Then, we will take on constructing a partial design for these interfaces. Finally, we'll briefly discuss directions for future work.

In this area there are number of political and legal questions around property rights, privacy, contract law, taxes and tariffs, and environmental protection. This paper largely elides these issues, as it attempts to see how far design alone can take us. The exception is that it is interesting to imagine how various designs could build the kind of evidence that would be suitable for advocating legal changes, as well as to see how design functions in different, but plausible, regulatory environments. In short, this paper engages the law, but the core purpose is not to advocate any particular policy change. Similarly, there are a number of possibilities for new technical development, but this paper will not require any new breakthroughs. If a speculative technology is mentioned, the purpose will be solely to communicate a possible opportunity, and a commonplace technology will also be provided as an alternative, although possibly at a lower quality of service. Even given these limitations, this paper will barely scratch the surface of this topic.

Unsituated Externalities

"A half-hour of use for an eternity in a landfill." The fact that this phrase corresponds to much of consumer packaging, and at a longer scale, most consumer goods, makes clear that we aren't well-equipped to take externalities (or even direct long-term effects) into account when making everyday material decisions. When a given participant in a material system encounters an item, these deficiencies occur before, during, and after the participant's encounter with the item:

- Past The item caused undesirable environmental changes or political conditions.
- Present The item may have unknown properties causing unknown health, safety, or performance

side effects.

- Future The item may not be able to be processed further, contributing to resource depletion, and causing health or environmental issues.

Many of the recent innovations in the information technology for industrial engineering have been to reduce these risks for producers, by creating tightly-integrated supply chains. However, users still largely bear these risks. Furthermore, users undertake these risks without the proper affordances for evaluating them. In fact, it is likely that this state of affairs leads to the sharp operational differences between producers and users, and it is likely that the emergence of new affordances will mean that the term 'user' will no longer be the appropriate description for this participant [21].

Closed-loop systems heavily mitigate these risks. Most obviously, closed-loop systems prevent resources being translated into waste material, preventing depletion and disposal problems in a single stroke. However, there are more subtle benefits. Logistical efficiencies, such as having all steps of the process located regionally, are more highly rewarded by amortizing benefits across even more usages, as are logistical reliabilities, by removing the need to produce from resource rich but unregulated regions. The possibility of further use of the same product encourages a higher quality, in maximizing the profit of selling to the next user with minimal restoration.

The information systems needed to capture these efficiencies likely face the same challenges needed to bring affordances to the user. The supply chain of an item would need to extend through its lifetime with a user and into new production. Although the supply chain doesn't strictly end with the retailer, as there might be a warranty exercised, or the product might be returned, there is usually no further record of the item's activities after it is transferred to the user. More importantly, the user doesn't have any access to the information, and more importantly yet, little use for it if they did. Therefore, there need to be affordances for transmitting the information to the user, for storing it, and for returning it with the product (or resulting component products). Although there is a great deal of design work that needs to be done in terms of transferring the information to the user and providing workable means for its storage and maintenance, there are many more challenges for post-transferring packaging items from the customer's possession efficiently.

The post-consumer user experience for packaging is mostly trash. Trash yields great convenience, but also the fastest possible way to mix all of the used products together in one lump. Recycling is a huge improvement, but in turn stands rather small when challenged with the possibility of reuse. Recycling currently demands a fair amount of attention, and possibly taking the item to a dump-like environment, but where recycling is supported it isn't particularly difficult. The central challenge is knowing when a given item will be recycled within a particular regime. In general, the more the number of kinds supported, the more specific handling is made possible, until at the finest granularity we are dealing with a particular product, a particular manufacturing batch, a particular item. For each of these, we are also dealing with reductions in the economy of scale for the immediately surrounding logistical steps.

At first, it may appear that the problem is that it is not worthwhile to recover cheaply-made items. While this is a criteria, it is perhaps more important to think about items from a materials-oriented perspective. Even a well-made item will fall apart, but if the original materials are accessible, then the item can be used to assemble other items. Furthermore, even though the items may last, individual items may not suit new social needs and arrangements. However, if the original materials are mixed, then the recovery of the individual material is more difficult. For each item, the form of recovery is different. For organic materials, it may be that the item should be composted and decompose in a natural environment. For industrial materials, it may be that the item should be warehoused and shipped in a particular way. Engineers can think of these processes as cycles where one must reduce entropy. Ecologists can think of maintaining different ecosystems [13]. Closed-loop methods are about making recoverable materials, and then providing the systems for recovering them, by preventing unrecoverable mixing at

the micro and macro scales.

As things stand now (as seen in the figure below), the consumer stands outside of the supply chain. As such, they aren't prepared to distinguish between products of different materials, nor are they equipped to undertake recovering their materials. Biodegradable products are still viable, but unfortunately our technology has quite a way to go until this is a feasible option for most of our products and packaging.

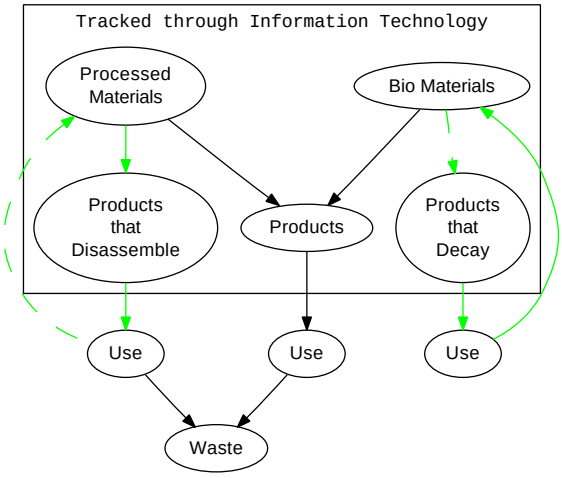

Figure 1: The Current State of Material IT Infrastructure

The challenge then is to communicate the supply cycles of the item so far, the material structure of the item, and what the material structure implies for future supply cycles. Let us momentarily leave this as an open question, in order to introduce application programming interfaces (APIs) as a design methodology.

APIs for the Real World

It may seem that designing application programming interfaces is an obscure way to go about any particular design problem: why should we use an artifact of computer programming to go about interaction design, much less industrial design or architecture? There are a number of good reasons for designing the API very early in a project:

- Mobile interfaces interrupt the experience of urban planning and architecture, and it is worthwhile to understand what needs cause these interruptions [10] [9].
- Architecture and planning often leaves gaps in which the interests of the user are not respected, in which the user could thrive with interfaces designed to arbitrate their interests for themselves [17].
- Interfaces introduce new concerns to design, such as system responses respecting the autonomy and dignity of the user[8], as well as to compensate for displacing physical cues inherent in mechanical goods [18].
- Interfaces will capture and then release data in a way that has political consequences, articulating a testimony based on what people do and what is sensed, as opposed to what is claimed, in a way that needs to be understood early in a design and communicated broadly to users [1]. Pollution sensors have been particularly interesting in this regard. [11] [4].
- Developments in interface-rich technology have already been proposed as a technique for mitigating sustainability problems. The next section will cover this subject in detail.

Beyond these reasons, there is also a commonsense reason for working on the API design early on: as the seam between infrastructure and artifact, the API has to be right for both. Before an infrastructure is imposed, we have to have some reassurance that the artifacts interacting with it can support the demands. Simultaneously, before designing an artifact, we must understand infrastructures under which the artifact will be expected to perform. The design of the API is a simultaneous exploration of both preconditions.

Immediate Precursors: Spimes and Open Scenarios

The use of interface design, within mobile and ubiquitous computing, as the core information technol-

ogy development for a cradle-to-cradle, sustainable manufacturing infrastructure is not a new idea. Instead, it was developed in an even broader technosocial vision in *Shaping Things* [21], which might also be called the spime technoculture. It observes that new capabilities in object production, logistics, and communication alter human-object relationships in society-changing ways, and that a further development is underway based upon technologies existing today. It should be possible to treat our objects as spimes, that is, objects trackable and searchable throughout space (*sp*ime) and time (sp*ime*) in a sustainable way, given a concerted effort of the following technologies:

- Unique Identifiers make information about the specific item accessible. Radio-frequency identification tags (commonly abbreviated as RFID and referred to as arphids throughout this paper) are a useful implementation for many applications, although they have a variety of privacy problems. Barcodes are another current identification technology and are already widely deployed, and have fewer privacy concerns, but at the cost of accessibility.

- Global Trackability makes coordinating transfers between items more straightforward. Various satellite location systems, including the Global Positioning System (GPS). Triangulating between cell-phone towers may be more plausible indoors.

- Search Tools allow the items on record to be found through search and generally facilitates finding objects in context. Google is one kind of search, based upon a massive organized and scored indexing of as much linked content as possible. Amazon and Netflix are another kind of search. Peter Morville's *Ambient Findability [14]* tries to follow many relevant threads in item search.

- End-user Design Networks are tools for end-users to create, share, and critique designs. Ideally, these tools are also subject to end-user design and customization themselves. Recently, there have been a number of free and open-source tools, including Sketch-Up, Processing, Wiring, Aurdino, and the platform work of BugLabs.

- Cradle-to-cradle Logistics examines the business decisions that need to be made in order to handle supply cycles efficiently. Other names for these developments include reverse-logistics (which considers the handling of returned, recovered, and recycled goods as self-standing problems) and closed-loop logistics (which holistically considers the problems facing the entire cradle-to-cradle supply cycle).

- Fabricators manufacture a broad class of items out of a common material, also ideally taking in a broad class of objects as input to be recycled. It is also desired that almost anyone has the ability to get and use one of these. These follow from a combination of programmable machine tools and 3-D printers, and current versions use plastic or iron pellets that can be melted down, but more work is being done to have a variety of materials and include electronic components.

Without losing sight of our initial goals, the APIs presented here could be seen as some of the search tools, end-user design networks, and cradle-to-cradle logistics that could support a spime technoculture. Of the other spime attributes, these interfaces require unique identifiers for items, but not necessarily that the identifiers be ambiently discoverable (although that helps). The APIs do require a certain ability to collocate individuals and items, but ambiently publishing the location of either is not required (although it helps). And, these interfaces do not require universal fabrication, such that any device can readily be assembled into any other, but the more readily that materials can be recovered and converted, the better.

Shaping Things and this paper have a tactical difference in their approaches to spime development. *Shaping Things* provides the following list:

1. "First, we have the capacity for identity - the code - which is modestly pasted onto the object."

2. "In the second stage, a much thicker and more

capable identity is embedded into the object, and that identity is historically traced."

3. "In the third stage, the means of production are re-engineered around the the capacity for identity. The object becomes an instantiation of identity. It's named, and it broadcasts its name, then it can be tracked."

The path from the thinnest, most concrete form of identity to the thickest, most abstract is not necessarily the same as the path of adoption. For one thing, going directly forward means that the customer will be encumbered with trackable ids for no articulated benefit. Instead, it seems likely that a more effective plan for spimes would articulate many mutually-enforcing adoption paths, with the understanding that the actual path of development will be messy. Here is a path of development these designs provide:

1. First, we develop scenarios - which articulate choices between the different paths of processing available to a specific material.

2. In the second stage, we juxtapose the material processing scenarios with specific products, bringing the historically-based decision making to material participants.

3. In the third stage, individuals and institutions identify their objects as participating in specific stories.

Scenarios are already part of the strategic portfolio of many companies, and also a handy artifact for user-experience design, but coordinating the development of scenarios directly with users, allowing them to choose their desired futures, is a new kind of user-interface strategy. The advantages of opening up the world of scenarios was articulated by Jamais Cascio [2]. The technique we will employ is to represent these scenarios in the kind of metaphors already understood in information architecture: tagging, scoring, and search. The prior work to this paper articulated a kind of scenario remixing platform that could be juxtaposed with situations via a tag-matching scheme [3], and this paper begins a focused refinement of this technology to sustainability applications.

API Designs for Material Contextualization

As noted earlier, appropriate cradle-to-cradle affordances mean that the privileges and responsibilities of material interaction are granted to producers and users alike. These interface will follow this principle so severely that not a single mode of interaction will differentiate between them. However, it does turn out that there are sensible organizing categories for differentiating between other aspects of the interface: identity versus role and choosing versus communicating.

Identity: Your identity is who you are, what you like, who you are associated with, and what you think about that.

Role: Your role is what you do, what choices you have to make, and what your responsibilities are.

Choosing: To choose is to make a change in responsibilities, relationships, and roles, at the cost of the opportunities lost.

Communicating: To communicate is to articulate to others that taking a given choice is a possibility, and that this choice will work for them.

Given these two aspects, we can describe four different categories depending upon which way we choose these aspects.

	Choosing	Communicating
Role	Situatedness	Story Strategy
Identity	Ownership	Brand

Interfaces in each category addresses a particular kind of question:

Situatedness: how does a participant come to understand the actions available to them, and the effect of these actions in a larger material ecology?

Story Strategy: how does a particular participant express and coordinate how their material flows work as part of a larger ecology?

Ownership: how does a given item become associated with and disassociated from a particular participant?

Brand: how does a particular participant present their ownership changes and arbitrate their reputation as such a participant in a set of material flows?

Let's start by looking at brand, which has interfaces already in popular use.

Brand: Communicating Identity

Through the internet and its many-to-many communication practices, a brand is not only what you say about yourself, but what others say about you. Amazon and Netflix are widely used consumer technologies, in which the items that you view, score, and buy are used to evaluate what else you may like. So, it isn't hard to imagine providing a score for an item.

```
item.score(score_value,
    score_criteria, scorer)
item.deleteScore(score_criteria, scorer)
item.deleteAllScores(scorer)
```

Since this is our first introduction to the interface, let's dig in a little bit, referring to Amazon and Netflix as examples. On the surface, this quite simply means that the scorer (say you) can provide a criteria-tagged score (if you learned a lot, say 0.9 on a -1 to 1 value for the 'educational' criteria) for the item (say, the book "Introduction to Machine Learning" by Ethem Alpaydin). However, there are a number of hidden slippery points already, coming from each parameter. Let us examine these individually.

First of all, when we rate items, we are often are rating all of the items that are the same kind (i.e. the same make, model, and year), instead of the the specific item. This often makes a great deal of sense, as manufacturing lines strive not to deviate from a particular design to the extent that a defect in one copy may speak ill about the process from which all copies are generated. Furthermore, we are likely rating media based upon the assumption that the contents will be the same, no matter which particular copy we are dealing with. For some items, they are sold as specific instances, and any problems will speak more to the overall reputation of the individual supplier, such that there is no difference between rating the design, the manufacturing processes, the delivery process, and the item itself. However, there are already many kinds of cases in which this distinction matters. For example, a low rating for a book based on a printing error mis-ordering the pages in a particular copy shouldn't necessarily reflect on the author. As another example, if we travel regionally, different bottling plants use local water when canning a soda, making the experience different. In general, we should always assume that a given rating reflects the most specific experience the scorer should be assumed to have had, and use the scoring criteria to explicate the matter. On Amazon, users will have expected the reviewer to have directly used the item being sold, while on Netflix, the reader may not have seen it at all. In a cradle-to-cradle production stream, a reference to the specific item is best, as that allows the assessment to be considered in the scope of the item's complete history.

The criteria can be a word, a comment, or nothing at all. Although the criteria can help explicate the item/kind confusion, the kind of criteria appropriate for a given circumstance also varies. When one looks at ratings on Amazon, one also reads what the reviewers have said, to determine what it was they liked or disliked about a given item. However, on Netflix, a simple score may be better, as it is much easier to say one prefers romantic comedies, or horror movies, or documentaries, without making an effort to say why one has this preference, and without any effort to articulate what one has in common with others who share this preference, as merely the effort of making a description can distort taste [7]. The purpose of these rankings is not to judge the item, but to categorize the taste of the user. Even though Amazon and Netflix are both 5 star rating systems about the same items, if software mixes these ratings without differentiating the different purposes for which they were produced, that would be a terrible mistake.

The value of a given score is also more complicated than it may initially appear. The way a given user uses the range of scores available to them will not necessarily correspond to any other user's without prompting. Even given a well-defined range, experts in a given subject will use vastly different areas of a range, given their style of applying expert judgment [23]. Even taking these issues into account, ratings can be severely distorted. A person may only rate an item if they feel strongly about it, particularly if the ranking is used to make further recommendations.

Finally, there is the matter of who is providing the score. In this case, the primary question is the different kinds of commitments they make. Do they

specify their criteria? Do they make a reference to a particular item? Is their ownership or use of that of that particular item verified? Do they claim to be a particular person, and is that claim verified? If not, do they associate with a pseudonym used to provide other scores? Generally, the scorers who make stronger commitments should also have their opinions be more strongly recognized, although of course this can work against the scorer, by having their scores more strongly disregarded. Amazon gives just a hint of this kind of distinction, with its 'Real Name' feature for reviews. There may also be more weight given to scorers with shared preferences, or belonging to a relevant social network.

Given all of this, where does that leave us? The simplest interface can leave behind the data suitable for simple use, and wider use after a great deal of analysis and reprocessing, but one should be very careful when working with score data not to overextend the results.

Given the ability to write scores, there should also be the ability to read them.

```
item.getScores()
item.getScoreCriterias()
item.getScoresByCriteria(score_criteria)
item.getScorers()
item.getScoresByScorer(scorer)
```

Once the scores have been retrieved, again, a great deal more analysis is possible with attention to the aforementioned background factors.

One issue that must be considered is accessibility, or how to provide these services to those without cell phones and home computers. In many cases, items in this API could be accessed from a computer in a public library, with mild inconvenience, where the items are associated with one's library card. However, in this case, for the scores to be useful they must be available at the time one is making a decision. One possibility is to create a system of access codes which would allow one to use someone else's cell phone. In poorer countries, this service may be marginally valuable enough as to allow the cell phone carrier to make a living. Another possibility is a system of kiosks, which seems a more viable possibility in richer nations. Here, the store could be eligible for government reimbursement if it could show it had shifted sales to items in a way that would reduce government burdens. By receiving compensation not (or, at least, not only) for the mere installation, but for results, stores might compete on kiosk design and features. Temporarily, at least, it is wise to limit our considerations to what is currently available, and circle back to accessibility issues in the context of other adoption pressures.

However, note that these methods make little reference to privacy and security. This is partially for readability, given the profusion of places where security could be applied, but this also leaves room for security to be applied anywhere between the score storage and presentation to the user, with all the usual security caveats. There is simply too much to cover already to discuss the issues of every commitment or specificity being private to a particular sphere, and so we leave this issue open for future work.

Scores are great for implicit finding, but won't necessarily be as helpful when explicitly trying to find something. Tagging, the application of many various short labels, have become popular through such applications as Flickr and del.icio.us, and are considered both a time-robust form of indexing [20] and a standard fixture of information architecture [15]. Given that tags serve a decentralized findability role, it only makes sense for them to be applied to objects.

```
item.tag(tag, [tag,]* tagger)
item.deleteTag(tag, tagger)
item.deleteAllTags(tagger)
item.showTags()
item.showTagsByTagger(tagger)
```

As an example, we could tag a loaf of bread as being low in sodium:

```
thisLoafOfBread.tag("low sodium", jane_doe)
```

If applied by a consumer, the tag would apply mostly to the brand, rather than the specific loaf, to be any use. For one-of-a-kind items, the producer has a trickier time of it: the only option to build any ongoing history is to back-link the loaf with a recipe.

Suppose that a supermarket price check scanner not only telling the shopper the price, but also comparative nutritional information. We may choose to omit the ability to recover who made the tag, but only show statistical distributions of tags in a controlled vocabulary.

Now we should talk about some of the interface challenges that need to be arbitrated to make these methods useful. First, let's look at search.

```
searchItemsByTag(tag, searcher)
searchItemsByScore(criteria,
    comparison_operator, value, searcher)
```

The appropriate responses of search methods depends a great deal on the application, device, location, user activity, and any number of other criteria. An auction site from home is different than at an art gallery on a laptop, both of which are different from on a mobile phone while retail shopping. The extent of items which should be found is not only a matter of design but also subject to political, business, or security-driven constraints between item suppliers. Consider the difference between the ability of users to browse items and prices on their own mobile phone, versus the range of items and prices available on an in-store kiosk. The kiosk is taken to articulate the point of view of the store. First of all, this means that the information available through the kiosk is an articulation of the store's values. Imagine if you can search for items taking nutrition and price into consideration. That store articulates a different set of values than one with a simple price-check scanner. Next, the searches that the user undertake might be subject to their judgment about the privacy they may be granted. For items of high privacy, the user may search first anonymously on the kiosk. Otherwise, the user may prefer their own device, to take advantage of their own tags and scores. The least preferred use is when one must disclose one's identity to make use of a particular capability of the kiosk.

These issues notwithstanding, it is handy to control the search results based on one's context [1]for oneself. In order to arbitrate this, we can tag the tags.

```
setContext(tag_or_criteria, context_tag,
    user)
removeFromContext(tag_or_criteria,
    context_tag, user)
viewContexts(user)
enterContext(context_tag, user)
leaveContext(context_tag, user)
```

`setContext` and `removeFromContext` are activities done when organizing the content a given context will invoke, either in preparation for entering a context, or fixing some deficiencies in one's view of it. In contrast, `viewContexts`, `enterContext`, and `leaveContext` all are activities undertaken primarily during the time of use, or just to testing to make sure everything is ready. Here are some example uses:

```
setContext("sodium",
    "grocery store", jane_doe)
removeFromContext("sodium",
    "grocery store", jane_doe)
viewContexts(jane_doe)
enterContext("grocery store", jane_doe)
leaveContext("grocery store", jane_doe)
```

We might imagine these contexts being useful outside of mobile use. Separating contexts for work, shopping, hobbies, studying, or entertainment can be useful, as well as topic-specific contexts.

Giving context-tags, we might also be able to suppose that there are geotags, or tags associated with locations. We are now at a point where we can imagine using location-linked information [12], but right now it seems like any centralized civic adoption would be a tough sell to municipalities without a common standard. Furthermore, with individuals able to access both location through GPS-enabled cell phones and geo-specific content through geotag microformats, it may be possible to have rich geographic applications adopted in a more decentralized way. For now, we will leave this subject open, except to say that context tags come from other sources than location and surroundings, but also reflect the

[1]To invoke context is to invoke a set of issues needing far more sophisticated treatment than another layer of tags [5], but it doesn't make any sense to drill into it without having introduced the role-driven aspects of these interfaces.

deliberate choice of what the user prefers to be doing.

In any case, these raw materials open up a wide range of collective intelligence possibilities for applications: tag, score, and context suggestions based upon existing shared tags, scores, and contexts. Contexts could be automatically assembled from tags and score criteria that are commonly accessed together, possibly being suggested to the user, and possibly merely providing easier access to these other choices. It is also possible to find sequences of contexts, specified or discovered, searching ahead for what could prove useful. Furthermore, any of this information could be shared, either in parts or linked together, manually or automated, anonymously or with some attached identity, arbitrated by shared tastes, common contexts, social ties, physical proximity, or direct communication. The pragmatic level of sharing may be heavily influenced by the roles it may allow oneself or others to take on. Those wanting to introduce a new brand will choose what to tag it, where those tags will be seen, and whom to review items and supply scores.

Situatedness: Choosing Roles

Let us defer talking about situatedness and roles, and instead pick up right where we left off: contexts implied by other contexts. Although some relevant information can be gathered by statistics over co-occurring tags and context tags, it doesn't go nearly far enough for giving people information they have and can put to good use. After going to the grocery store, the shopper heads home, to put the groceries away, to no longer be physically encumbered by them. That's all well and good, but we also know about other contexts, namely those implied by all of those purchases. Buying a bottle of orange juice means that the shopper has about a week's worth of orange juice and are encumbered with the bottle, and the history of that bottle of orange juice is now contingent on their choices. Buying the item has caused a change in situation, both for the shopper and for the bottle.

Perhaps before buying the item we would like to know a little about the history of the item (which we are now considering sponsoring), the current state of the item, and the possible futures for the item.

```
item.showCurrentSituation()
```

If the current situation of an item is merely all of the tags associated with that item, then we don't need anything more involved than what we already have. But, just to avoid confusion, let's assume that we can group tags together. This grouping could be implemented any number of ways, including tagging all of these tags with the same tag, which we have already committed to. Using hierarchical groups of tags it's easy to describe an item.[2]

```
(description
 (plan
  (assemblage
   (part
    (material Polyethylene)
    (dimensions (height etc)
                etc))
   (part (material CarbonSteel)
         (dimensions etc))
   (join etc)))
 (location etc)
 etc)
```

At this point, the reader should keep in mind that a number of assumptions have not been made:

- This would almost never be the form of presentation used by anyone.
- There is not yet any commitment to standardize (or not standardize) these tags.
- There is no assumption that this description comes from the producer of the item, nor is there any assumption that the description is correct.

Finding the right representation doesn't necessarily need to be resolved as part of this paper (and will be designed differently in different implementations, platforms, vendors, etc.), but standards and veracity should both be addressed. First, let's look

[2]Please pardon the use of a lisp-like notation as opposed to the more verbose, but more widely-used XML.

at standards. Instead of describing a standard, what one would like to do is describe the kinds of services which would require constraining the structure of the tag sets, yet be popular enough to make maintaining these constraints worth the trouble. For example, one might wish to retain the distinction between assemblage and material, as well as a description of how these materials are joined and the amount of each material, as this would mean that cradle-to-cradle material-processing operations could tell what could be recovered from the item, and at what expense [19]. However, in order to justify these constraints, one would need to create and distribute an application that could be widely used for this purpose. Therefore, the obligation on this paper is to show that an interaction between structure-using programs and potential users is a credible possibility.

Now, let's look at veracity. Instead of creating locked-down portions of the tag space and legislating veracity from the very beginning, which requires a complex top-down administration, we should ask ourselves under what conditions a given set of tags is suitable for a particular purpose. In some ways, this recapitulates the earlier discussion in the credence given a particular score: the more relevant commitments they make and meet, the better the tag is likely to be. These include the same kinds of basic commitments (and commitments by others to them) as before, as a source will be more credible:

- the less anonymous the tag provider
- the more connected the provider is within the social network
- the more people using the same tag
- the better the scores from your social network and from similarly well-scored others
- the longer the track record of verifiable claims with legally-enforceable consequences for non-compliance

However, many of the most credible claims will come from potential users of the tags. The tags describing a given situation may mean that the item is usable in a later process, such as in the materials reprocessor. If a materials reprocessor respects the materials tags of a given source, and they credibly make purchase decisions based on those tags, then those tags have a strong testimony indeed. Let us describe the way that an object changes tags (and thus changes its situation) as a particular path through a scenario, which includes all the ways the item could have changed its tags.

```
findScenarios(item)
```

Just as the user changes from context to context, so do items, only usually in a much more fixed and discreet way. If we'd like to look at what our item might have in store, we might choose to look at histories we might suppose other similar items have had. There are two ways to build such future histories:

- actually figure out a way to record the future situations of a given item and index those situations in a searchable way.
- make them up in a plausible way.

Making up plausible scenarios is a more realistic option to start with, isn't as terrible as one might think, and can lead to recordable situations. Let's start with a practical example. A given grocery store could assume that, say, 95% of the buyers of milk will consume it locally and throw away the carton in a conventional way, if there is no municipal support for recycling. Knowing that those cartons compose a given percentage of the surrounding landfills could be useful, in case that particular kind of plastic proves worthwhile recovering, or how much of an obstacle these cartons pose to recovering other materials. But, if this kind of assumption was searchable, a recycling firm could insert a scenario-specific advertisement for their services. If this firm keeps a rough account of how many pounds of each kind of recycled material they recover, they could even make up rough numbers to give back to the scenario. Specific people might even indicate that they are subscribed to the service. In this case, a credible claim about a different alternative will likely come ahead any specific numbers, but hopefully will lead to their development.


```
scoreSituation(situation, score_value,
     score_criteria)
```

In the technical implementation, scoring a situation is very much like scoring an item, but in embedded practice, it opens up some rather interesting possibilities for analysis and interface intervention. How much is a person willing to pay to get a better score for a particular criteria? How much does that willingness depend upon other labels and tags the person has made? How does the willingness change if the score improvement is attributed to them?

Of course, not only can we score present or future scenarios, we can also score the past.

```
item.showHistory()
```

`showHistory` will show claims about the actual history of situations, while `findScenarios` will include possible histories. This is a very useful tension, similar to the tension regarding the current state and composition of the item. Spurious but plausible negative assessments being linked to the history of an item should compel those with an interest to make credible claims about the real history of an item. This in turn leads to claims about the effects of that history and ongoing efforts to arbitrate them.

Situations in closed-loop processes can recur, which means that over the long-term, the difference in assessments between situations will recur. This means that closed-loop processes can be incommensurately better than their terminating counterparts. The argument is relatively straightforward: even if it is initially more expensive to guide an item through a cradle-to-cradle system than to mine the natural resource and then throw the item away, when the natural resource is depleted, it may be vastly more expensive to recover the thrown away item (if it is possible at all), such that the number of people deprived of the item due to the marginal expense of recovery are more than compensated by those who will be able to enjoy it in an arbitrary number of later cycles. Keeping track of history means that those who undertake expense to recover objects will accrue a continual (although marginally decreasing) share of credit for their intervention as further cycles increase the overall value of their initial action.

Overall, the objective of opening up scenarios to people, having them rank historical situations and future outcomes, make material decisions, and form their own affiliations and history as a result is allowing them to choose their role. By seeing the history and the future possibilities, users are situated in the context of their material choices.

Story Strategy: Communicating Roles

People can not only make situated choices about what role they want to play, but they can also communicate potential roles.

```
item.markItemWithDesiredSituation(situation,
     desired_situation, owner)
item.listDesiredSituations()
item.removeSituationMark(desired_situation,
     owner)
findItemsByMarkedSituation(situation,
     owner)
```

Marking an item with the desired situation is like putting the item up for sale with a contract attached. Even if the desired change isn't supported for this item and user for whatever reason (for example, the user couldn't find a local buyer), this call could be used to show that the user made an attempt. There are many serious accessibility and usability issues with this method, however. Before, we could reasonably assume that the user was in a public place, within reach of a phone renter or kiosk, but when the user actually wishes to get rid of the item, they are at home. It's possible to imagine door-to-door phone renters, or street-corner kiosks, serving a similar role to disposal as to acquisition. Even trickier than the accessibility issues are the usability issues, as the user may turn over a fair number of items, each of which now needs individually marked as available, creating a considerable amount of work. In the ownership section, we'll turn our attention to some arphid-based affordances, but for now we note that, without heavy-duty technological instrumentation, only strong social or legal pressure, or true scarcity, could likely motivate this work to be done even for items of packaging. It's wise to imagine a partial implementation for the relatively privileged

coming to terms with a more ad-hoc, yet more comprehensive, disruptive solution emerging from areas already experiencing true scarcity.

Another way to communicate potential roles is scenario publishing. Earlier we mentioned a recycling firm publishing their scenario in a grocery store.

```
scenario.publish(publisher)
scenario.retract(publisher)
```

Just as the recycling company probably didn't invent the recycling technique, they probably didn't invent the scenario completely either. Instead, they probably remixed an existing scenario by adding and removing tags from situations, as well as creating, deleting, and copying situations from any number of other scenarios.

```
scenario.addSituation(situation, author)
scenario.removeSituation(situation, author)
situation.alterSituation(added_tags,
     removed_tags, author)
scenario.connectSituations(
     previous_situation, next_situation,
     author)
scenario.disconnectSituations(
     previous_situation, next_situation,
     author)
```

Sometimes you don't want to have your scenario associated with these situations everywhere. You may just be learning how design scenarios, doing scenario fiction, consulting about possible scenarios, or only competing within a local or regional market. In this case, you might select a venue.

```
scenario.publish(venue, publisher)
scenario.retract(venue, publisher)
```

Scenarios can be scored and tagged, which allows for the kind of processing mentioned throughout.

```
scenario.score(score_value,
    score_criteria, scorer)
scenario.tag(tag, tagger)
```

Scenarios could also make reference to contracts. This has the downside that a bad promise looks authentic, but it could be possible to scan the contracts, matching those that don't match trustworthy templates, flagging them for review, and inviting negative judgment of credible sources.

```
item.markFitnessForPurpose(situation,
     desired_situation, contract, guarantor)
item.removeFitnessForPurposeMark(
     desired_situation, contract, guarantor)
```

Altogether, by putting forward scenarios, judging them, adding contracts around them, and marking your items as serving specific roles within them, social scenarios can be used to communicate roles.

Ownership: Choosing Identity

Ownership is one of the furthest challenges these kinds of interfaces. In order for ownership to become a factor in these systems requires the both the strongest kinds of commitments ("I take responsibility for the situations this item has caused, is causing, and will cause"), and also a great amount of effort and mindfulness. Therefore, specifying not only the interfaces, but also the physical and information affordances is critical to handling ownership.

From the point of view of sustainability cycles, ownership is most interesting at its seams: acquisition and release. In acquisition the primary problem is taking on the specs and supply chain information necessary to keep the cycle going. In release, the challenge is arbitrating where both the object and its information will go.

```
item.acquire(owner)
```

The identity of products is often uniquely known. The barcode has been widely adopted for consumer goods, and it appears that industrial consortiums around arphids are doing well. If you are a company, you may also have the good fortune of having the equipment to read the ID, and the information infrastructure to look up what it means. However, if not, you have to have the information transferred to you. This is a two-step process even if the second

step is automated. In the first step, the ID is transferred to your account, and in the second step, you retrieve the item associated with the information.

The first barrier is bundling all of the unique ids together, which is commonly done anyway. After this, they must be transferred. There are many different possible ways of handling this change.

- The ID transfer be handled as an additional service of a credit or debit card payment for the purchase. At an additional expense, the credit-card owner could pay for a public-key encryption service.
- This could be done through store-brand discount card.
- This could be sent to an email address, possibly a temporary address. If you don't provide an email address, the information could automatically be sent to a generated web page, with the address and passcode on the receipt.
- The information could be transferred to a mobile device directly.
- The items themselves may be able to broadcast this information via arphids.

Let's consider the last item in depth, as arphids have a fair number of benefits. They would allow local findability, allowing consumer APIs for asking which items they own, and where they now are. The materials issues of sustainability could also be made much easier, by using the arphids to automatically sort trash. Arphids also reduce the number of activities undertaken at the point of purchase, by allowing the path of the item to be tracked without explicitly declaring the new user as owner. However, the range of transmission of arphid tags is determined by both the tag and the tag reader, such that no long-term guarantees can be made about range limitation for the basis of privacy of a particular tagging system as tag reader technology advances [24]. Although limited disclosures can be very useful, full involuntary disclosure of ownership creates a variety of problems: targeting for theft, blackmail, industrial intelligence, etc.

In spite of the lack of security through range limitation, arphids could be widely adopted nonetheless. Even though an item has an arphid tag, it might not actually be part of any particular coding scheme, with the item/arphid correspondence built and transferred at the time of purchase. However, this would remove some of the benefit of it being used in a supply chain. Another possibility is that there are two address spaces, one public and one semi-private, and through the use of a tear tab, the code of the id is changed (and possibly also changed back through a second tear) by closing a switching circuit. This is not impossible to imagine, as consumer-tearable tabs for range reduction already exist [16]. It could also be that arphids are widely introduced outside of the public eye, and that privacy will only be allotted to the observant, the paranoid, and to those wealthy enough to avoid houses built with electromagnetic shielding (as is already the case in some houses today [6]).

In any case, purchase-point transitions are likely enough, as even with arphids, more wrangling likely has to be done in order to get all of the items tagged, scored, situated, marked, and published appropriately.

Having talked about taking on ownership, it's now appropriate to talk about the even more complicated situation of relinquishing it.

```
item.transfer(situation,
     desired_situation, owner, new_owner)
item.transfer(owner,
    new_owner)
```

Here are two flavors of transferring ownership from one user to the next. The top one is really the best the original owner could hope for: the accepting user will agree directly to what they are using it for. In particular venues, this may carry legal weight, while in other venues, the call may be disallowed for people who haven't met that obligation. In any case, the owner will usually get credit for trying, unless the new owner has a history of not meeting this obligation and they should have known better. The other call is less picky, but you take on greater risk to your reputation for not specifying what you might have wanted, although the risk depends upon the reputa-

tion of the new owner at the time of transfer. Sometimes you just can't find anywhere to transfer your good, and you have to throw up your hands and give up.

```
item.throwAway(owner)
```

Throwing away an item relinquishes ownership, and it may also leave the item in a known location. Of course, this doesn't do much for one's reputation, but it can't do too much harm, or else people will be payed just to accept transfers and take the hit on reputation themselves. Also, there is the possibility that people will just silently abandon the item. Items held can count as negative reputation: if you are buying orange juice, milk, and trash bags, but not throwing away any of them, may lead to a worse reputation than tossing them, because you're forming a private dump. Think of it as a perpetual property tax.

```
item.recover(situation, recovering_agent)
```

Recovering an item means bringing it out of a non-ownership situation, or finding it. This corresponds to a suitable reward in reputation, similar to receiving the deposit on the back of bottles. This reward should not be so extravagant as to trigger theft. Of course, recovering an abandoned item should paint the owner in a negative light. The penalty for abandoning an item should be severe, but not so severe as to trigger spurious lost or stolen reports.

```
item.reportLost(owner)
item.reportStolen(owner)
item.reportLostOrStolen(owner)
```

Here is way to claim that, among other consequences, that you'd like to temporarily defer responsibility for the original item, as it has lost your possession against your will. This clearly should be used judiciously, and claims that items that are typically thrown away underwent this fate (your 20 bags of orange juice cartons were stolen) should be regarded with skepticism.

However, there is a problem with this model. You could form a big enough cycle of moving garbage around that it would be unintelligible from a real cycle. We could call this phenomena garbitrage (a portmanteau of garbage and arbitrage).

It's a very good question if this is still in the realm of social software and its implicit governance, or requires more conventional regulatory intervention. Although there could be incentives for the development of these social systems, and social pressure is both more potent and more palatable than legal pressure, there are regulatory interventions worth making, three of which are listed below.

- Impose uniform refund deposits across industries, or at the very least remove laws against collusion for raising the prices of refund deposits.
- Watch and catalog the material traffic across borders, to prevent the loss of recoverable materials and to check against unverifiable bogus ownership transfers.
- Try to encourage international logistics standards for transferring item tag structures across borders verifiably.

Summary

Let us recap the story so far: by more widely distributing scores and tags, the raw materials of information architecture, the facilities for searching, building, and ranking scenarios are also developed. Merely by placing the ability for tag sets to lead to other tag sets, allowing for hierarchical tag sets, and maintaining networks of trust, we allow participants to express usable ideas about sustainability. These same networks of trust that allow a particular interpretation of a tag set also allow for arbitrating the dynamics of use. The desire to arbitrate and participate can then lead participants to undertake more specific commitments.

These aren't the only possibilities; there are many other cross-interactions possible between these components, so a series of scenarios are being developed to explore different adoption paths. In particular, social logistics are a great tool for those living in workable poverty. It is very handy to know where food, shelter, and other essentials are to be had, at what cost, and how reliable this source seems to be.

Cell phones are already being purchased by the rural poor and being put to good use for this very purpose [22]. If we can provide those selling cell phone services with additional tools, they may have a competitive advantage. If economic struggles become widespread, it may rapidly create new adoption pressures.

However, in the meantime, it's worth remarking about a particular feedback loop. If these connections are made, then the drive to use these connections for the next step should drive deeper adoption.

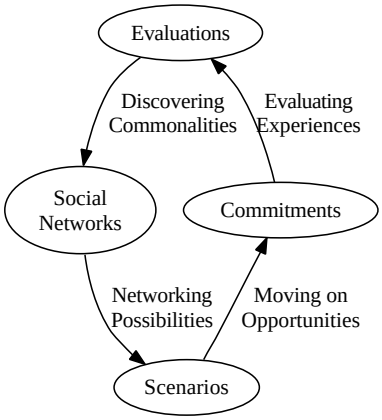

Figure 2: More use of evaluations should allow you to discover friends-of-friends with similar preferences. More people in the network should present a wider array of opportunities. More opportunities mean trying out new things. More experiences lead to changes in preferences and evaluation.

Given all this, where do we stand in terms of our initial goal: to develop interfaces that provide better affordances for sustainability? Below is a figure that shows what we might prefer. First of all, the user is now a participant of the IT infrastructure. Choosing products of combined, unsalvagable materials is reduced, while the paths for reverse logistics are made clear. Better reverse logistics also lead to a reduction in trash, while the remaining trash is tracked for the benefit of future recovery technologies. The development of biodegradable products has matured.

Except for the last objective, this interface could help mitigate all of these factors. Ranked scenarios could reduce the desirability of unrecoverable materials by showing alternatives and reducing the repu-

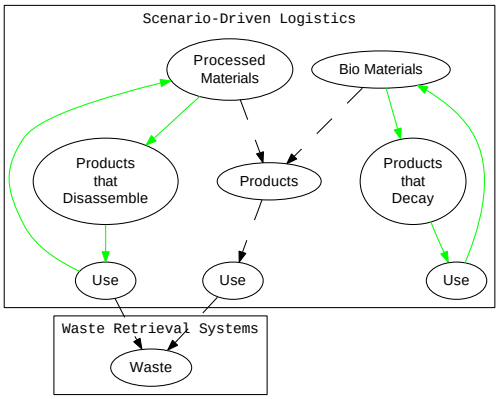

Figure 3: The Objective for Material IT Infrastructure

tation of those goods. Recovery could be facilitated by marking used goods as ready to be transferred. Trash could be reduced through losing reputation against other opportunities, and otherwise tracked as a matter of shoring up reputation against further loss. Having all parties able to access, search, develop, tag, and rank scenarios could overcome the producer/consumer IT divide.

Future Work and Conclusion

There have been a number of points for future work that have been raised within this paper. First of all, we have to understand the actual mechanics of the interfaces better, to see if the interfaces can disclose their intent in a verifiable and trustworthy way, such that people could actually trust disseminated scenarios, their evaluations, and the specific historical interactions they are based upon. We have to see if the technology can perform scalably, reliably, and securely. We also have to understand and specify the specifics of the interfaces, to make sure that they are actually usable and accessible to the public they are designed for. We also have to understand the different ways the technology could manifest itself, building shared components and undertaking the infrastructural and policy challenges facing adoption. Beyond this, we need to develop criticism for these interfaces, to see what perspectives are missing and what factors are unaccounted for.

To tackle these problems, we're going to develop scenarios for adoption, to discover uses that the interfaces need to account for. We will prototype user interfaces, to discover usability and accessibility issues. We will implement and test prototypes, working to flesh out verifiability and security issues. And, we will continue writing, looking into related material and researching other essential background information.

The most important future work, though, is to engage with the reactions to this paper, responding to criticism and working with collaborators. Hopefully this paper contains enough ideas to cause others to undertake both their own elaborations and their own API designs, and also to look at the idea of publicly distributing open scenarios as a serious option for sustainability. Together we will figure out ways to wrangle post-consumer resources for our own desires.

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