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On the meaningfulness of data in product design for lifetime optimization

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Abstract
Planned obsolescence is generally considered as a negative business strategy that induces replacement needs and affects attachment dynamics, as opposed to the goal of elongating product lifetime. At the present, however, an early replacement of long-lasting products is preferred in at least two cases which can be addressed during the design stage i.e. when the cost of maintaining is higher than product benefits and when there are environmental reasons to replace obsolete products. Furthermore, designing meaningful products that help the user in his/her daily activities, while addressing environmental issues, could help affecting attachment even in standardized and utilitarian products, such as home appliances. In this study, the holistic view and the management of the complexity of Systemic Design, combined with the use of the IoT technologies are proposed using the refrigerator as a case study. Acquiring information is considered as a tool for product innovation; the data is divided into (i) static data, related to the product and (ii) dynamic data, which derive from the context of use and interaction with users. The latter can be acquired by investigating the object's daily use and environment, with data acquisition through quantitative tools (sensors) and qualitative ones (feedback, questionnaires, interviews). IoT and data retrieval open a variety of possibilities in monitoring, accessing more precise knowledge of products and households useful for design purposes. This paper seeks to demonstrate how IoT can support and trigger a design transition towards more durable products and components, by focusing on sustainability and simplifying people's lives in daily actions.

Introduction

Planned obsolescence is a well-established business strategy whereby the product is designed to lose value rapidly (Agrawal et al. 2016; The Economist, 2009; Aladeojebi, 2013). It generally occurs indeed when manufacturers deliberately accelerate product lifecycle by introducing new features or technological improvements and by stimulating fashion changes (Mugge et al. 2005) which in turn negatively affects the experienced attachment to the currently owned product and induces replacement need. Both object obsolescence and replacement could be fostered when the product shows a deteriorated appearance or an aesthetic wear, e.g. when objects could not return to their original appearance even after cleaning. The aesthetic diminishes (shiny surfaces become dull) and the product goes out of fashion, (Byrnes, 2010). As Papanek (1985) claimed, product obsolescence occurs both aesthetically and technically. We could also add functionally. Technological obsolescence is dictated by manufacturers and occurs when new products make the previous ones incompatible. At any time, indeed, the manufacturer of connected objects may decide to stop running its product, e.g. ceasing the updates and making it obsolete in no time. It may also happen that the object experiences a decline in performances. In this case, the object is felt as outdated by a specific target, but it can still be seen as satisfying by other users. Industrial product design should be challenged and reconsidered to address environmental sustainability issues, such as elongating life spans of products, developing products adaptable to local and regional resources and conditions, and enabling product maintenance, repair, upgrading, etc. (Bakırlıoğlu and Doğan, 2012). However, these three aspects of obsolescence would be even more challenging if placed into new dynamics and new sustainable business models.

Two issues can be addressed in the early design stage, for which designers are called to anticipate and avoid their occurrences.

Cost of maintaining higher than product benefits

It occurs when the cost for maintaining is higher than product benefits or even unsuitable compared to buying a new product. In this case, we are considering products whose pieces are out of production, the failure of essential parts such as the engine for the car or parts designed to be non-replaceable. Designers should, therefore, anticipate this undesirable effect, by designing products that can always be updated, disassembled, repaired and maintained. Moreover, in addition to the product, both designer and companies should envision the spare parts network and consider services related to the upgrading operations. We should necessarily avoid and delay the replacement of a product when it still works and the user still wants to use it.

Environmental reasons to replace obsolete products

While planned obsolescence is generally considered a negative strategy, in the specific case of durable goods (e.g main appliances, vehicles, heating systems) extending the product lifetime is not always a sustainable choice. Replacement of obsolete products could be motivated by environmental reasons and could be subsidized by tax incentives to speed up the removal of such products from the economy, pushing the consumer to replace his old devices in favor of more sustainable or less harmful ones. As Mugge et al. (2005) suggested, a sensible evaluation of the environmental desirability of early replacement compared to extending product longevity can be performed evaluating the interrelations among three parameters: (i) the initial environmental impact of the replacement product, (ii) the possible improvement of energy efficiency, (iii) the expected usage time. Once again, the designer can do his job by anticipating and doing research before making design decisions, considering the harmfulness of the materials and gases involved. Upgradability and the choice of a modular design could allow the replacement of a technologically obsolete part, preserving the operation of the product.

Research focus: home appliances

We look specifically at everyday objects, in which an interaction between people and technology is expected. At present for products with a relatively high energy-efficient improvement, early replacement is preferred over product longevity (Mugge et al., 2005). Home appliances are addressed in this paper as a case study example of criticalities listed above, adding to these also disassembly issues because, although the volume of this e-waste in people's perception is overestimated, it still accounts for about 2% of the landfill space (Zimring and Rathje, 2012). Appliances have a recovery rate of 57% (Center for Sustainable Systems, 2016) as they are mainly made of metals, however, cannot establish what happens to the 43% non-recyclable part. Another aspect to consider is that home appliances are considered as utilitarian, standardised products, unable to trigger attachment dynamics (Mugge et al., 2005), whose purchase occurs almost exclusively for functional reasons. However, since appliances are a means to do a task faster or easier, there is room for improving performances and useful life in the early design stage. The user, indeed, seems to want them to last longer, avoiding wasting money in their early replacement unless specified conditions change. The need for bigger appliances or house remodelling and renovation are among the primary replacement reasons, together with the demand for new features, while the replacement of a worn-out appliances remains the most common purchase motivation (Mintel, 2016). Considering these long-lasting products, there is room to address the replacement motivations combining them with an extension of the useful life, providing services and maintenance for the products. This scenario could radically change by introducing new strategies and business models such as strategies to reduce product ownership through sharing, remanufacturing activities and so forth. Another strategy can be combined with the previous ones to address the same issue, i.e. extending useful life by redesigning meaningful and high-value products. For example, when a product provides a more efficient and personalized service, the consumer is expected to develop new relationships with it and disposal may be delayed.

Methodology

We defined a methodology (Figure 1) to address the lack of perceived benefits in connected appliances (Accenture Interactive, 2015; Gfk, 2016), by shifting the focus from "technology push" solutions, to "need pull" ones. We hypothesized that the current lack of data and experiments to understand the actual use of appliances leads to lost sight of the original aim of them (Fiore et al, 2017), i.e. help the user and simplify daily user operations (Berg, 1994). Thus, we started from the broad research question "how to define a more sustainable home system?" by choosing to focus on the refrigerator. This appliance resulted from a multi-criteria decision process (Fiore et al., 2016), which included the level of interaction with the user and the environmental impact of the product. The refrigerator, though, seems to be an appropriate starting point also as it is the only appliance directly involved in the food waste, cooking and preparation operations and tasks, as well as being the only stand-alone appliance, connected to electricity but not to the water network.

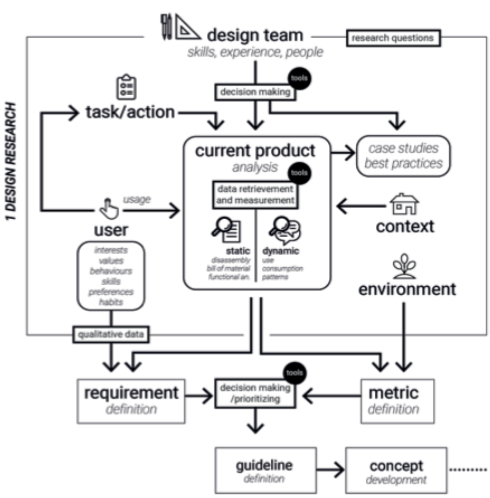

Figure 1. Methodology

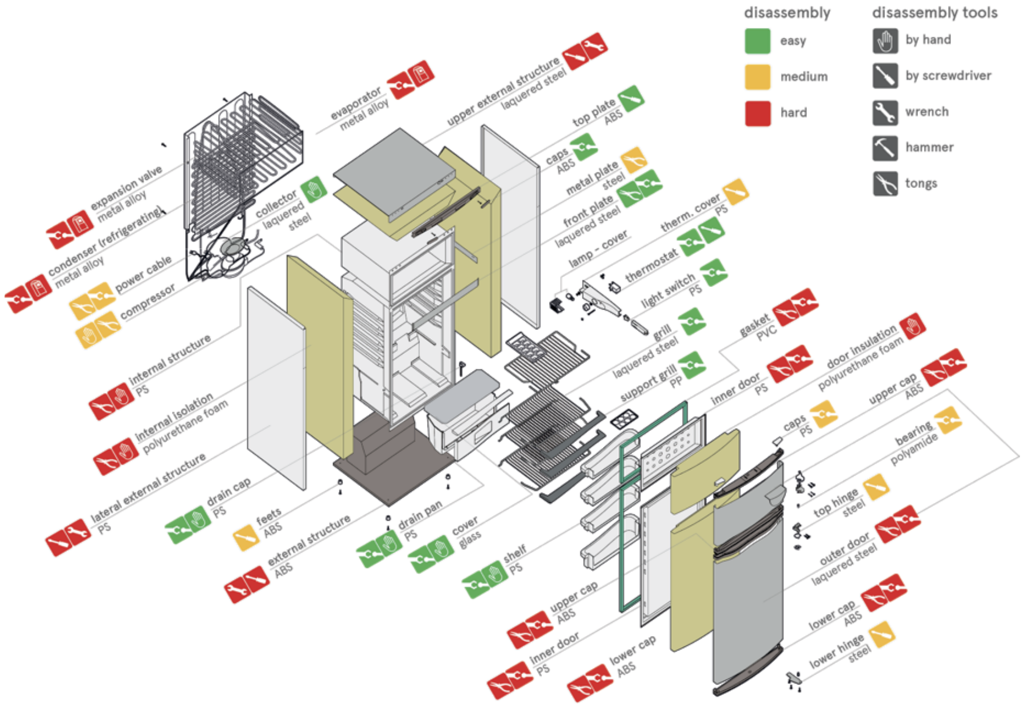

Figure 2. An example of a product (a refrigerator) broken-down into its individual components.

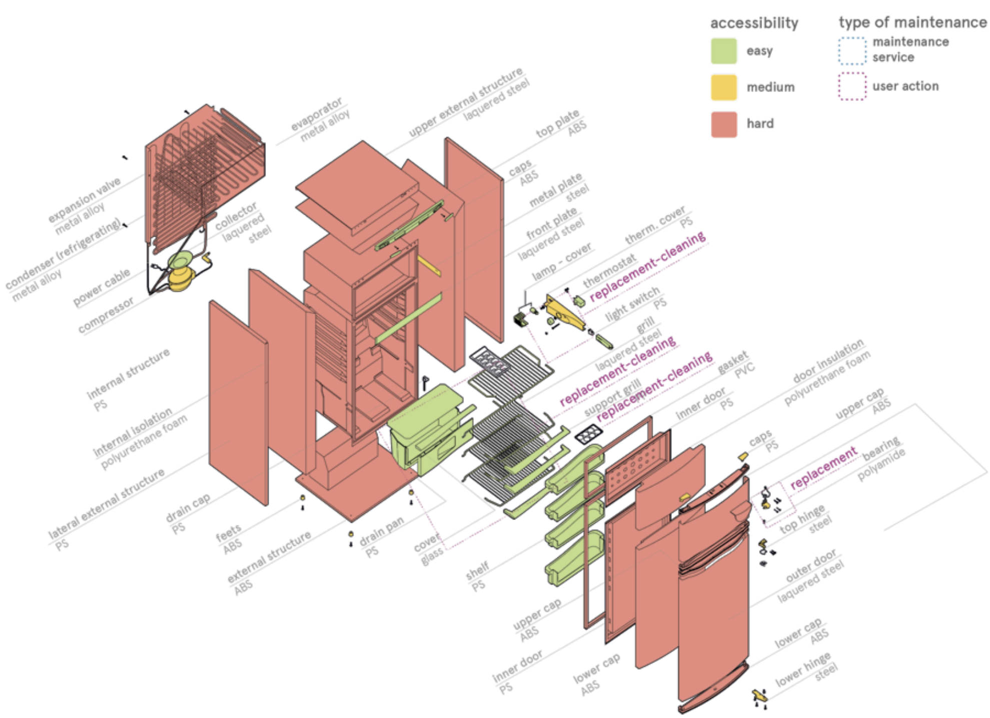

Figure 3. Maintenance.

We need to step back and identify which operations the householder should perform and then detect which actions are involved. In this case, the main task we identified is *"storing food at the right temperature to fulfil the expected duration"*. From there, all the other actions such as the door opening derive directly from the design choices that someone in the past has made, namely the decision that the solution should be a refrigerator. Therefore, considering and focus only on that object prevents the designer from questioning on whether the refrigerator is really needed and 'the growing role of refrigeration in today's Western food system' (Kuijer and Bekker, 2015), not considering other agents of change and assuming the availability of that appliance. For that reason, we decided to group into the section 'case studies and best practices' high and low-tech solutions that have been given to conservation in general. In parallel, we analysed current refrigerators and we looked for a feasible solution to address the task now. Since the refrigerator object has already been defined, we jump into the product analysis to understand the room for intervention for designers.

Data Retrieval

What was immediately clear to us was the non-privileged designer's point of view, which does not have the complete overview about the object to design and would require certain data to design, which are currently not available. We can divide the missing information about current products into static data and dynamic ones.

Static Data

Static data comprehend the technical material, such as drawing and model for studying current shapes and dimensions, bill of materials (BOM) to understand how many different materials are involved, the related weights, questioning why designers chose that material (i.e. are there any physical- functional- performance reasons behind the choice?). We also include disassembly or product dissection (Figure 2), in which the product is broken down into its components, understanding the ease of performing the disassembly and the tool needed. The same analysis made on disassembly can be maintained on maintenance (Figure 3) by considering the ease of access for each part.

Eventually, the functional analysis (Figure 4) allows providing alternatives for each functional group of the current product, understanding which parts are required to perform specific functions, which parts depend on the design solution chosen.

This is a method for a reverse engineering capable of extracting information from a physical object. It could be thus performed on every worn-out object to deconstruct it and understand its functioning through the analysis of its parts, having the possibility to disassemble, measure and observe it. This tool should help designers to question, understand, reconsider each part or group of parts and their function individually.

Dynamic Data

Using the refrigerator as a case study, we implement our methodology through a pilot experiment, highlighting the need for dynamic data related to the real use of refrigerator, i.e. the object in relation to the user. We instrumented two refrigerators over a week with sensors to detect light, energy consumption, inside temperature, humidity and noise, external coil heat dispersion. We assumed power consumption as a reflection of the refrigerator's activity and the light as a reflection of user interaction (Figure 5),

Figure 5. Assumptions.

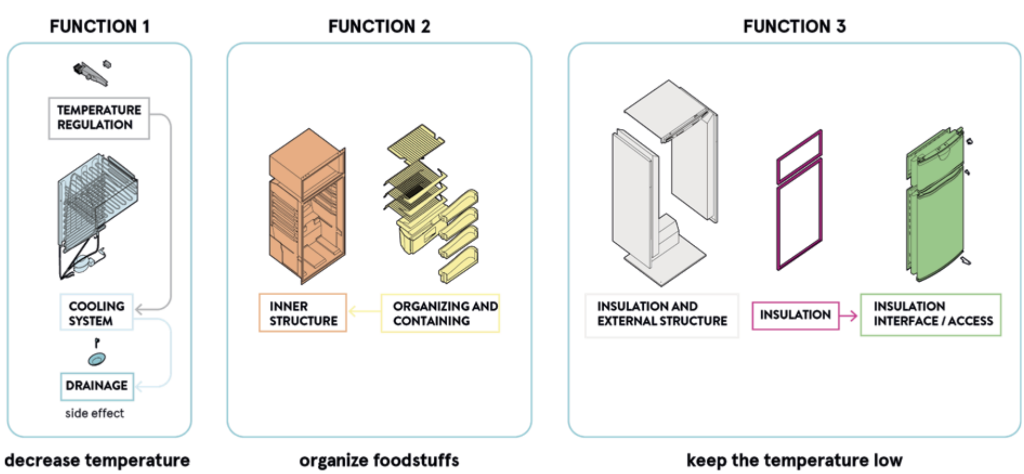

Figure 4. Functional analysis.

we combine these two indicators with the other variables and eventually we reflected on the data to extract design insights (Fiore and Bourgeois, 2017).

From an in-depth analysis of data broader conclusions are drawn, specifically on the potential benefits of using IoT indicators to detect different situations directly related to the use or object-specific data. The Internet of things (IoT) could help indeed to collect missing information about both the object and its use, to address critical aspects in the design stage thus extending products' lifetime. Below we discuss how the knowledge gained from data and the potential of IoT could become valuable intelligence and can be leveraged in the design stage. IoT data represents a whole new class of information: quantifiable knowledge about the operation and performance of products (Henne, 2015) during the use phase.

Diagnostic, predictive maintenance and user alert

During the first experiment, we detected that energy patterns are highly recognizable, being characterized by activity and inactivity alternate phases. The first conclusion is that with the aid of IoT learning system the refrigerator could alert the user when it experiences energy anomalies, preventing cooling failure, noise and water leaking, up to prevent the refrigerator breaks (Fiore and Bourgeois, 2017). The designer can consider the fridge as a unit, but also investigate group of components or a single part. The design team could consider just one indicator for understanding one aspect of the product or analyse multiple/aggregate indicators to understand and detect more complex dynamics, correlations and patterns. This could be the case of the following three examples considering (i) functional groups (fig. 4), (ii) essential components or (iii) parts that are subject to wear. The first case is a system of parts grouped by a specific function, the second are those parts whose breakup will compromise the whole product functioning, eventually leading to replace it. Some relevant parameters should be defined and verified by measuring them through ad hoc experiments on these components, providing a more precise knowledge about the system. For this reason, both criteria definition and thresholds setting are important decision-making steps. The third case is represented by parts subjected to wear, which can also be monitored with ad hoc experiments, to make their recovery suitable for a second valuable use of components or materials. Data about the real use of a product can be collected for a short time, with an object instrumented for the experiment. Then the R&D or design team could make projections over time of the expected use to determine when the object should be replaced or updated to obtain the maximum value from it. This stage would require analytics to measure and combine data inputs over time (Henne, 2015). Monitoring some parameters of the refrigerator as a form of predictive maintenance could also affect new business models (PTC Inc., 2015) and value-added services throughout the lifecycle, being particularly relevant for the circular economy.

Ongoing Research

Currently, most of the IoT development for everyday applications relies on a technology-push, connecting things and collecting data with a limited use of the information and a poor experience. In the home context, Mennicken and Huang (2012) highlight that smart technologies are those fitting householders' routines, avoiding unnecessary work. We identify five potential steps to extend everyday objects' lifetime by using IoT technologies:

Detect: collecting the information related to the goal to achieve, through means balancing benefits and constraints.
Control: adapting product operation to the specific use or context.
Predict: anticipating and preventing breakdown based on pattern of use.
Communicate: contextual awareness about the potential risks (and reason), providing advice to improve the product lifetime.
Share: product use and operation can be shared and aggregated to detect more complex correlation and patterns of use leading to product breakdown.

These steps must be tested during the next months with a pilot study planned on a larger number of dwellings, using a platform of communication with the user.

Conclusions

This paper seeks to demonstrate how IoT can support and trigger a design transition towards more durable products and components. The proposed strategy is suitable for both current product-centred economy and a future service-centred one. It provides some guidelines and directions for future studies that want to address the extension of the life cycle, based on predictive maintenance while promoting an efficient use of products. IoT and the data collected open a variety of possibilities in monitoring, accessing more precise knowledge of goods and households, useful for design purposes. Many smart interventions can be done on appliances before talking about connected products, pointing out the difference between 'smart' and 'connected'. Among them detect failures in advance, notify, inform, communicate are only a few possibilities and it raises the need for learning systems able to recognise patterns, together with a platform on which to share and communicate directly with the user. Introducing the flow of information in the design process is important to reach the overview on products. Moreover, every designer could question the product in different ways, according to the heterogeneity of the working team. On the one hand, this data collection can lead to improve current products and their maintenance (proactive monitoring, remote control, predictive maintenance), introducing services (meaningful information to the user, interaction with other connected things such as the supermarket card, predictive food shopping). On the other and it could lead to develop new products more focused on sustainability, simplifying people's lives in daily actions.

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