INTRODUCTION OF THE REUSE METHOD:
RETRIEVING KNOWLEDGE FROM EXISTING PRODUCT DESIGNS

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ABSTRACT
In today’s marketplace, most products must better satisfy customers’ needs in the shortest time and be competitively priced. In this context, the reuse of knowledge about the targeted product is critical for developing potential product platforms. One can facilitate the reuse of existing knowledge to achieve a desired design by establishing a method that considers the layout of modules (or components) with identified flow interfaces, volume and the fundamental functional description. The problem grows with the number of candidate modules and with information-rich descriptions. The proposed REUSE (Reuse Existing Unit for Shape and Efficiency) Method greatly facilitates this search by filtering candidates based on their similarity to desired characteristics and their performance efficiency. By reusing existing information from components and modules, this approach allows the detailed specification of cost (e.g., investment and production cost for a module) along with other desired characteristics. This method applies to the complete product realization enterprise from conception through product launch. It also enables traceability of design decisions to help capture rationale and justification. A case study involving a family of cameras illustrates the proposed method.

1. INTRODUCTION
The power of reusing knowledge in design is not exploited to its full potential. For instance, camera maker Kodak Company has designed over 700 different models of cameras (about 70 single-use cameras). But when a new model is developed, design teams do not have any systematic method to identify, extract, and reuse the relevant existing information. A method to reuse existing design knowledge can retrieve the best experiences of more than 100 years.

The interest of the reuse activity is described by Pahl and Beitz [1]; Deutschman, et al. [2], among others. Designers can avoid “reinventing the wheel” by employing a reuse approach. Based on well-known existing designs, the reuse activity (1) increases the traceability of the product, its standardization, quality, and control, and (2) decreases its cost, potential problems and design uncertainty. In terms of project development, the reuse approach increases the convergence, and decreases the lead-time. This paper builds on previous work from Alizon, et al. [3] that describes the modeling of the reuse of existing product-process configurations.

The context of the study is the Computer Aid Design (CAD) environment when designers specify the design of a module or a component. This product design activity takes into account the desired characteristics of the new product and translates these qualitative and quantitative characteristics into technical solutions. The result is the associated components, modules and structure. Designers have to consider the volume of the product, interfaces between components/modules, static and dynamic behaviors of the product, manufacturing, and assembly activity. The challenge is to take into account these aspects and to converge to a final product that satisfies both customer needs and objectives of the company. Additionally, these companies typically have a lot of collected experience (from both their successes and mistakes) which they are unable to exploit. Thus, designers are able to benefit from the extraction of useful design knowledge.

The aim is to provide a method for identifying and extracting relevant design information from a design repository. More information on design repository can be found in Stone
The designer can then reuse the entire design, a subset of artifacts, or, at least be inspired by the existing designs. This approach also provides information on the quality of the designs because the existing designs have already been tested by the customers. In order to address the problem of extracting the right information, several questions have to be answered:

- How to identify and extract similar designs?
- How to identify and extract remaining efficient designs?
- How to configure the relevant information?
- More generally, how to assist designers and still allow them to use their expertise?

The related literature of this research field is presented in Section 2; a method for approaching the design is proposed in Section 3, where the three associated stages are detailed. A case study based on single-use cameras is presented in Section 4. Finally Section 5 discusses conclusions and perspectives of this work.

2. RELATED LITERATURE

The potential benefits of reusing information in design are now clearly recognized and many works investigated this research field. For the reuse of product information, it is first of all important to focus on the repository that supports the design knowledge. In this field, various methods have been developed for reusing standard components:

- Automatic analytical selection by Vogwel and Culley [7];
- Textual, pictorial and empirical data by Croft and Harper [8];
- Cost estimation techniques by French, et al. [9];
- Knowledge-Based selection from Wood [10];
- Design audit facilities by Akoumianakis and Stephanidis [11];
- And user enhancers, by Webber, and Bradley and Agogino [12,13].

A more detailed description of these methods is given in Culley and Webber, and Sivaloganathan and Shahin [14,15]. The interest for users and suppliers are reduction of cost, lead-times, and a better control of the process design. Culley also dealt with the reuse of sub-assemblies [16]. The current method is based on a specific process to reuse non standard modules/components design information.

3. METHOD TO REUSE EXISTING MODULE-COMPONENT DESIGN INFORMATION

For each component, the product’s characteristics (PC) are introduced to define the product information. Two categories of information are specified: the desired information represented by the desired product’s characteristics (PCd) and the existing knowledge, addressed by the existing product’s characteristics (PCe). The existing manufacturing’s characteristics (MCe) are also used to find the manufacturing cost and the investment cost. The REUSE method considers the desired characteristics of the new product and those of existing products in order to examine the similarity for potential reuse. The associated manufacturing information is then added to assess the efficiency of designs based on desired criteria.

The information data model highlights the repository, the desired and existing data, and the global extraction process as shown in Figure 1. The process starts with the desired product (on the left), searches in the repository (represented by the grey arrow) to find the best matches with the existing designs and returns to the desired product project with the relevant design information.

### Figure 1: Data model for the extraction of similar and efficient information

The REUSE method is composed of three sequential stages:

1. **Similarity Study**: this first “filter” checks the similarity between the desired module characteristics and the existing modules in the repository.
2. **Efficiency Assessment**: this stage assesses the efficiency of the modules remaining after the first stage. At the end of this stage, the most relevant designs are proposed to designers who finally choose the best design(s).
3. **Configuration**: this last stage assists designers in configuring the best design information.

The goal of the REUSE method is to be integrated into a CAD software and to address a design repository. The global method is presented in Figure 2. The similarity study stage filters the data from the repository and transfers the closest existing designs to the efficiency assessment stage. After selecting the best solution, designers use the configuration stage to specify the reuse of the existing module information.

#### 3.1 Stage 1: Similarity Study

Knowledge management in non-standard module design is based on (1) similarity of existing design information and on (2) the efficiency of the remaining designs. Desired Product Characteristics, PCd, are compared to existing Product Characteristics, PCe, of product modules saved in the design repository. This similarity study is used to filter existing modules to a set of a reasonable prescribed size.
3.1.1 Criteria for the Similarity Study

Regarding their contribution to study similar designs, four criteria are selected for this similarity study:

- **Function(s) of the module**: A module ensures one or more functions. Different functions generate different final designs; thus, the function name, and the number of functions for each module are checked to be sure that the modules are similar in a function description. It is assumed that the function name is generic for this study. Hence, the function name is consistent within the repository (see **Conclusions** for future work on this aspect).

- **Design value**: Even with a similar function, a difference of the design value has an important impact on the final design. For instance, even if the function “view the scene” is the same for two cameras, the design values “infinite” and “zoom 1.35” bring different final designs.

- **Volume of the module**: The environment of the module is another constraint. In this case, it is important to integrate the volume of the module to ensure that existing module will fit in the desired environment. The unit is cm³.

- **Matrix of Interface Flows (MIF)**: The module is represented by a parallelepiped with interfaces on each face. These interfaces permit flows (visual, mechanic, fluid, electric, etc.) in or out. Based on this parallelepiped, the interface flows are modeled by a matrix that takes into account the number of flows on each face. When this method compares two parallelepipeds, it must consider the possible symmetry between the two parallelepipeds. To facilitate the computation, the matrix of interface flows takes into account the two largest surface area (a, b), the mediums (c, d), and the smallest one (e, f); thus, the parallelepiped is defined by (a, b, c, d, e, f). The aim is to match the MIF of the desired module (a, b, c, d, e, f) and the MIF of the environment (a, b, c, d, e, f). Figure 3 gives an example of the construction of the matrix of interface flows for the viewfinder component of a camera.

In this case, the top face has one interface flows, “view exposure count”. The side face has two interface flows: “view scene” and “Flash info”.

3.1.2 Process of the Similarity Study

Designers select a desired module (PCd) and look within existing designs (PCEs). Based on the criteria of similarity, the desired module is matched with all the existing ones. The similarity study is inspired by the Fuzzy Set Theory proposed by Zadeh [17] that admits the possibility of partial membership (similarity). A normal distribution is used for each criterion to assess the similarity of sets Eq. 1. The mid-point of the Gaussian is the desired design. The shape of the Gaussian enables scoring in the same way of the existing designs which are below and above the mid-point. Based on this Gaussian, each existing designs are scored on the desired design. Thus, this score represents the distance between the desired and existing information and also serves to specify the level of reuse (develop in the configuration stage). Figure 4 represents the scoring of existing designs and also the level of reuse specified by designers. Designs selection are controlled by a user-defined threshold. Under a certain similarity score, it is considered that an existing design is too far from the desired design. This threshold can be modified by designers to filter more or less designs, based on the number of designs in the repository, the type of module, etc.

\[
P(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-(x-\mu)^2/(2\sigma^2)}
\]

After each existing designs is scored, the next step is to rank each existing designs. For that, different methods can be used: K-Nearest Neighbor Method, Cover and Hart [18], Bayesian Method, Jaynes [19], Discriminant Analysis Method, Dipillo [20], Artificial Neural Network Method, Fogel, et al. [21], Decision Tree Method, Breiman, et al. [22], permit finding the nearest couples of the desired one. For this similarity study the Electre1s Method by Roy [23,24] is used. This method is based on outranking each PCE to the PCd for each criterion (function, design value, volume, and MIF), taking into account the preference and indifference of designers, Figure 5 (for a classic case of increasing preferences).
Condition of non-discordance: even if $e$ over-ranks $b$ (considering the average of criteria) it is possible that one of the criteria $e$ does not over-rank $b$. If the gap between $e$ and $b$ for this criterion is important, it is critical to take it into account. Thus, this condition verifies the non-discordance for each criterion with $b P_j a$; for more details see Roy and Bouyssou [25].

![Figure 4: Gaussian scored similarity between PCe and PCd](image)

**a- Resolution model of Electre I's method**
- $E$ is the set of couples, $E \neq \emptyset$
- $F = \{g_1, g_2, \ldots, g_n\}$ a set of criteria
- $\omega_j$ coefficient positive modeling the importance of the criteria (with $j \in \{1, \ldots, n\} \text{ et } \sum_{j=1}^{n} \omega_j = 1$)
- $B^h$ the set of existing couples belong to the family $h$ with $B^h = b^h_j$ for $h = 1, \ldots, k \text{ et } i = 1, \ldots, l_h$; the number of criteria is the same for all the $h$ family studied. $b^h_j$ corresponds to the $j^{th}$ couple of the $h^{th}$ module.
- $B$ the set of existing $E$ with $B = \bigcup_{h=1}^{k} B^h \text{, } B \neq \emptyset$
- $q_j$ the threshold of indifference for the criterion $j$
- $p_j$ the threshold of preference for the criterion $j$

For the assembly time criterion, the preference is modeled by:

**Concordance index**, Figure 5: is the concordance index modeling the degree for which $g_j$ is in favor of the indifference relation.

$$C_j(e, b^h_j) = \frac{p_j [g_j(e)] - [g_j(e) - g_j(b)]}{p_j [g_j(e)] - q[g_j(b)]} \quad (2)$$

**Global concordance index**: takes into account $C_j$ is balanced by the relative importance of the criteria.

$$C_j(e, b^h_j) = \frac{\sum_{j=1}^{m} k_j c_j(e, b)}{\sum_{j=1}^{m} k_j} \quad (3)$$

![Figure 5: Modeling the preference for the assembly time](image)

A robustness test generates a final graph and enables the identification of the core of the graph of the most similar designs. When the existing design is identified, it is ranked at the first position, and remove from the list of studied design, the Electre I's Method is performed again until there are no more existing designs to study. Thus, at the end of this similarity study, all existing designs are scored and ranked from the closest to the farthest. The different levels of reuse for the last stage “Configuration” are assigned for each PCe based on their similarity score.

### 3.2 Stage 2: Efficiency Assessment

As all the remaining designs are similar, the method then focuses on the efficiency assessment. This stage ranks the remaining designs based on six criteria presented below. Designers must be involved in this stage to finally choose the best design. The expected outcome of this stage is to identify the most efficient and similar design(s) among the repository.

#### 3.2.1 Criteria Selected to Assess Efficiency

For the current study six criteria are retained to assess the efficiency of the similar designs. These criteria can be adapted to different products. Table 1 describes the selected criteria.

#### 3.2.2 Process of the Efficiency Assessment

Every remaining existing design is scored in terms of efficiency. Based on these scores, existing designs are ranked in descending order from the most efficient.
Table 1: Synthesis of criteria selected for the efficiency assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Cost</td>
<td>The cost of the product helps to assess the efficiency of a design</td>
<td>$</td>
</tr>
<tr>
<td>Manufacturing investment</td>
<td>This criterion represents the investment that company has to make to produce this module in the factory</td>
<td>$</td>
</tr>
<tr>
<td>Quality</td>
<td>Based on the previous use of the product, customers' suggestions improve the quality of the design</td>
<td>-</td>
</tr>
<tr>
<td>Control score</td>
<td>The control score is important when the product is already used across generations and less important when it is a new module</td>
<td>-</td>
</tr>
<tr>
<td>Similarity score</td>
<td>The score of the previous stage is used to take into account the similarity between the desired and existing module</td>
<td>-</td>
</tr>
<tr>
<td>History</td>
<td>This criterion is qualitative and refers to remarks that every services (designers, manufacturing, sales, distribution, etc.) have made on the existing module</td>
<td>-</td>
</tr>
</tbody>
</table>

This ranking process must integrate a multicriteria approach because objective functions of some criteria are opposite (e.g., maximize the quality and control score, and minimized costs). The Electre I is used again for this assessment; here the final core of the graph corresponds to the most efficient design. Finally, designers, assisted by those scores, with the history, and also with the geometric model of each existing module, choose the best existing design(s). Thus, designers can specify the final design within the configuration stage.

3.3 Stage 3: Configuration

At this point, the “best” existing design(s) are now identified. The CAD environment and the experience of designers are also inputs of this stage. The expected outcome of this stage is to help designers to configure the best existing design(s) to satisfy the current design requirement. Based on the similarity study, there are several levels of information reuse. The reuse is complete if the similarity is perfect and partially complete when score of similarity becomes less important. Trouse [26] introduced four levels of reuse which are listed from the most similar to the least (see Figure 6):

1) **Direct and complete**: the desired and existing designs are exactly the same; therefore, designers can directly copy the existing geometric model and paste it on into their CAD environment.
2) **Quasi-complete with adaptation**: the similarity is good but not perfect, so designers have to make some adaptations, taking into account the differences. This is also a copy and paste process, but in this case, modifications are needed to fit the exact desired design.
3) **Design with artifacts**: desired and existing designs do not fit exactly, but designers can use some good ideas from several existing designs to build their own solution. Designers can also Copy and Paste the different artifact in the CAD environment and afterwards modify, erase, delete or create components to satisfy the needs.
4) **Nil**: there is no existing design information to present to designers, because the desired module is a new module.

Figure 5: Modeling the different levels of reused information

After the configuration stage the REUSE method is complete. Designers can design another module until all are defined.

4. CASE STUDY

4.1 Perimeter and Data

The case study addresses seven single-use cameras by Kodak®: Water & Sport, Black & White, Max Flash, Max HD, Plus Digital, Max Outdoor, and the Advantix Switchable model, as shown in Figure 6. Three modules/components are considered for the study: viewfinder, film holder, and shutter, as shown in Figure 7.

Figure 6: Single-use cameras by Kodak® use for the case study, from the left to the right: Water & Sport, Black & White, Max Flash, Max HD, Plus Digital, Max Outdoor, and the Advantix Switchable

The study is composed of two parts; the first one takes the characteristics of the Max HD model as desired product characteristics PcD. As this camera is already in the repository (PcE), the REUSE method should ideally point to the existing Max HD design (PcE); thus, validating the REUSE method.
Figure 7: Pictures of three modules/components use in the case study, from the left to the right: viewfinder, film holder, and shutter

The second test uses the new Kodak Zoom® as the desired characteristics. This product is not in the repository, but already exists on the market. A comparison of the resulting product from the REUSE method and the actual Kodak product will be helpful in assessing the efficiency of this method.

Depending on the data available in the different companies, the accuracy of efficiency can vary. In the example provided, due to the few data available, estimates are used, but it does not affect the methodology. Thus, for this study, the product and manufacturing costs are merged. The manufacturing investment can be summarized by the price of the mold and can be neglected for this study. Quality and history are not known. Furthermore, efficiency is linked to the product and its market; thus, the criteria selected for this study can be adapted for another product. The content of the repository is shown in Table 2.

Taking the example of the viewfinder of the Max HD, the repository shows three functions for this component: view the scene, view exposure count, and display flash status. The respective design values are “infinite” (a focal focusing to infinite is used to view the scene), “x2” (a magnifying glass is used to see the exposure count), and “True” (the design value of this function is binary, 0 or 1). The volume of the viewfinder is 3.1 x 2.5 x 2 cm³. For this example, the MIF is 1/0/2/1/0/0 with 1 visual flow on the largest face (to see the exposure count), 0 flow on the other largest face, 2 flows on the first medium face (1 for the display flash status and 1 to view the scene), 1 flow on the other medium face (to view the scene), 0 on the two smallest faces of the parallelepiped (see Figure 3). Symmetries of the parallelepiped are checked to ensure the coherence of the similarity.

The total cost of this module integrates manufacturing cost, material cost, and operating cost Thevenot and Simpson [27]. The value of 0.0118$/g is chosen for the plastic parts; a value of 0.0225$/g is chosen for the metallic parts. The operating cost (machine + operator) is estimated to 60$/h. In these conditions, the estimated price of the Max HD viewfinder is $0.0767. The control score is equal to 2, because this module already exists in several earlier products.

### 4.2 Implementation

#### 4.2.1 Similarity Study

Each PCe-PCd couple is scored automatically by a Gaussian curve, using a C++ program. Scores are presented to the Electrels method which then ranks existing designs in descending order, starting with the most similar.

The solver keeps the most similar PCe-PCd designs and eliminates the existing designs that are too far away. The C++ program builds the Gaussian distribution and gives the score for every criterion, where the middle point is the value of the item checked (PCd). The distribution of the Gaussian is specified to have the value 0.5 when the value of PCe is half the value of the PCd. The design is considered too far when the score of a couple is less than 0.6.

By experience, the weights of criteria are specified as follows: “function” is 3, “design value” is 2, “volume” is 1, and “MIF” is 1; designers have the control of this weight that can vary from a product to another and from a module to another. All criteria are based on increasing preferences. For each criterion, if the threshold of the preference is 0.2 and the indifference is 0. The level of concordance is 0.66. The following criteria are implemented as follows to study the similarity:

**Function:** the functions of the module are compared by their name. The number of functions of the desired design gives the middle point to build the Gaussian. For every existing design this Gaussian gives the location scale Gaussian density at the existing design value. The method finally scores the similarity from 0 to 1.
**Design value:** The process is the same as “Function Item”, the desired design value gives the middle point and every existing design is scored from 0 to 1.

**Volume:** Every face (large, medium, and small) is compared. The score varies from 0 to 3; 3 if the three values of the volume of the existing design fit in the desired volume. The middle point of the Gaussian is 3; every existing design is scored based on this value.

**MIF:** Flows are compared by largest, mediums, and smallest faces. All symmetries are checked and the similarity is scored from 0 to 6; 6 if the six faces has the same number of flows. The process is equivalent to the volume criterion.

### 4.2.2 Efficiency Assessment

To keep the heterogeneity of the criteria, the same Electres method is used to find the efficient design among the similar ones. Based on all criteria this method builds an outranking graph defined on the set of potential alternatives assessed by the criteria. The “control score” and “similarity score” have to be maximized, and the cost has to be minimized. The “control score” is rated from 0 to 2. If the module is in the repository for the first time, its value is 0; if it is already used by one product, its value is 1 and if the module is used by several existing products, its value is 2. There is no veto; other characteristics of the implementation are given in Table 3.

### Table 3: Characteristics of the implementation for Electres

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Type of Preferences</th>
<th>Threshold of Preference</th>
<th>Threshold of Indifference</th>
<th>Concordance</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control score</td>
<td>Increasing</td>
<td>0.2</td>
<td>0</td>
<td>0.66</td>
<td>1</td>
</tr>
<tr>
<td>Similarity</td>
<td>Increasing</td>
<td>0.2</td>
<td>0.66</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Decreasing</td>
<td>0.1</td>
<td>0</td>
<td>0.66</td>
<td>2</td>
</tr>
</tbody>
</table>

Regarding to the configuration stage, basics functionalities of the CAD are used: Copy-Paste, Modify, Delete, View, Insert, etc.

### 4.3 Results

As described in the previous section, the Max HD camera was studied in order to prove that the REUSE method would point back to an existing design when given identical PCd and PCe constraints. That investigation was followed by a similar study on the Kodak Zoom Camera. That second study hoped to show that a new design produced by the REUSE method matches a product that Kodak already manufacturers but that was not present in the repository.

#### 4.3.1 Max HD Camera

**a- Similarity Study**

Table 4 gives the location scale Gaussian density for Max HD against all existing designs in the repository. The shaded modules are “filtered” and not considered for the rest of the method.

These scores are then ranked by the Electres method. For the viewfinder, this similarity study stage retains Black &White; Max Flash; Max HD models (they share the same viewfinder). For the film holder, every existing design is kept. Part of this result is because the different film holders are very similar. For the shutter, Black & White, Max flash, and Max outdoor are filtered (due to the threshold under 0.5 for the item design value); Water & Sport, Max HD, Plus Digital, Advantix are kept for the efficiency assessment.

**Table 4: Results of the Similarity Study for the Max HD**

<table>
<thead>
<tr>
<th>Module</th>
<th>Existing design</th>
<th>Function</th>
<th>Design Value</th>
<th>Volume</th>
<th>MIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>View-finder</td>
<td>Water &amp; Sport</td>
<td>0.54</td>
<td>0.55</td>
<td>0.41</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max flash</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max HD</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Plus Digital</td>
<td>0.54</td>
<td>0.25</td>
<td>0.8</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Max Outdoor</td>
<td>0.54</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Advantix</td>
<td>0.08</td>
<td>0.25</td>
<td>0.14</td>
<td>0.41</td>
</tr>
<tr>
<td>Film holder</td>
<td>Water &amp; Sport</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max flash</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max HD</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Plus Digital</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max Outdoor</td>
<td>1</td>
<td>0</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Advantix</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td>Shutter</td>
<td>Water &amp; Sport</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.41</td>
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<tr>
<td></td>
<td>Black &amp; White</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td></td>
<td>Max flash</td>
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<td>0</td>
<td>0.8</td>
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</tr>
<tr>
<td></td>
<td>Max HD</td>
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<td></td>
<td>Plus Digital</td>
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<td>Max Outdoor</td>
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<tr>
<td></td>
<td>Advantix</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
</tr>
</tbody>
</table>

**b- Efficiency Assessment**

Based on Electres, results of this stage are given in Table 5.

**Table 5: Results of Efficiency Assessment for the Max HD**

<table>
<thead>
<tr>
<th>Module</th>
<th>Viewfinder</th>
<th>Film Holder</th>
<th>Shutter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water &amp; Sport</td>
<td>-</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Black &amp; White</td>
<td>1</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Max flash</td>
<td>1</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Max HD</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Plus Digital</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Max Outdoor</td>
<td>-</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Advantix</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

For the viewfinder, the Electres method gives the three remaining designs ex aequo (this component is the same). The film holder of the models Advantix is ranked first followed by the Plus Digital and Water & Sport models. The Max HD shutter is ranked first with the Plus Digital model.

**c- Configuration**

The balanced similarity with the viewfinder matches perfectly. Thus, a “Direct and Complete” reuse can be performed. For the film holder, the best design comes from the Advantix because there is no component for this function in this model (cost = 0). With the digital definition, designers will see that the bottom cover of the Max HD is different from the Water & Sport and the Plus Digital model. So, the Max HD or Max flash (same component) is selected as the best design, the balanced similarity is equal to 1 so the level of reuse is “Direct and Complete”. For the shutter, the Max HD design is selected;
its balanced similarity is equal to 1 and can be reuse at the “Direct and Complete” level.

4.3.2 Kodak Zoom

This study explores the potential for the REUSE method to return existing designs to facilitate a new design, the Kodak Zoom. The desired characteristics for the Kodak Zoom are given in Table 6.

Table 6: Characteristics of the Kodak Zoom (PCd)

<table>
<thead>
<tr>
<th>Module</th>
<th>Function</th>
<th>Design Value</th>
<th>Volume</th>
<th>MIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewfinder</td>
<td>View scene</td>
<td>Inifinite</td>
<td>3.1 x 2.5 x 2</td>
<td>1[0][3][0]</td>
</tr>
<tr>
<td></td>
<td>View exposure</td>
<td>x 1</td>
<td>4.3 x 1.9 x 1.9</td>
<td>1[1][1][0]</td>
</tr>
<tr>
<td>Film</td>
<td>Hold film</td>
<td>27 (exp)</td>
<td>3.8 x 2.9 x 0.7</td>
<td>1[1][1][0]</td>
</tr>
<tr>
<td>Shutter</td>
<td>Obtrurate</td>
<td>800 Iso</td>
<td>1</td>
<td>1[1][1][0]</td>
</tr>
</tbody>
</table>

a- Similarity study

Results of the location scale Gaussian density for the Kodak Zoom are given in the Table 7, where the shaded modules are filtered.

Table 7: Results of the Similarity Study for the Kodak Zoom

<table>
<thead>
<tr>
<th>Module</th>
<th>existing design</th>
<th>Function</th>
<th>Design Value</th>
<th>Volume</th>
<th>MIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewfinder</td>
<td>Water &amp; Sport</td>
<td>0.14</td>
<td>0.55</td>
<td>0.41</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>0.14</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Max flash</td>
<td>0.14</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Max HD</td>
<td>0.14</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Plus Digital</td>
<td>0.01</td>
<td>0.25</td>
<td>0.8</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Max Outdoor</td>
<td>0.61</td>
<td>1</td>
<td>1</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Advantix</td>
<td>0.14</td>
<td>0.25</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Film</td>
<td>Water &amp; Sport</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Max flash</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Max HD</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Plus Digital</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Max Outdoor</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Advantix</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Shutter</td>
<td>Water &amp; Sport</td>
<td>0.5</td>
<td>0.61</td>
<td>0.41</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Black &amp; White</td>
<td>0.5</td>
<td>0.14</td>
<td>0.01</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Max flash</td>
<td>0.5</td>
<td>0.14</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max HD</td>
<td>0.5</td>
<td>0.61</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Plus Digital</td>
<td>0.5</td>
<td>0.61</td>
<td>0.1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Max Outdoor</td>
<td>0.5</td>
<td>0.14</td>
<td>0.8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Advantix</td>
<td>0.5</td>
<td>0.61</td>
<td>0.1</td>
<td>1</td>
</tr>
</tbody>
</table>

For the viewfinder, the similarity study stage retains the Max Outdoor existing designs. All other models are filtered by this first stage. For the film holder all the existing designs are kept. For the shutter, there is no existing similar design and the study is stopped.

b- Efficiency Assessment

Results of this stage are given in Table 8. For the viewfinder, with the Electres method, the only remaining existing design is the Max Outdoor. The efficiency assessment of the film holder still gives the Advantix first (no component), followed by the Plus Digital, the Water & Sport and the Max HD-Max Flash, ranked from best to worst.

Table 8: Results of Efficiency Assessment for the Max HD

<table>
<thead>
<tr>
<th>Desire design</th>
<th>Viewfinder</th>
<th>Film Holder</th>
<th>Shutter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water &amp; Sport</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Black &amp; White</td>
<td>-</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Max flash</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Max HD</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Plus Digital</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Max Outdoor</td>
<td>1</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>Advantix</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

c- Configuration

The balanced similarity score of the viewfinder (0.75) places the reuse level at “Design with artifacts”. With the digital definition, designers will notice that the bottom cover of the Zoom is different from the Water & Sport and the Plus Digital model. So, the Max HD (or the Max Flash) is selected as the best design and the balanced similarity is equal to 1 so the level of reuse is “Direct and Complete”. Finally, for the shutter there is no similar existing solution.

4.4 Analysis

4.4.1 Max HD

Results for the Max HD are interesting in several aspects. First of all, the existing viewfinder, film holder, and shutter of the Max HD design have been found by the REUSE method when applying its own characteristics. This result validates the interest of the method. The three stage process has shown its interest by selecting the similar designs and efficient design. In the case of the shutter, the efficiency assessment stage points to the efficiency of every design. For the film holder, the method identifies the relevant information to assist designers to choose easily the best design.

4.4.2 Kodak Zoom

The Kodak Zoom case is interesting because it is quite different from the rest of the family. The volume of the product is specific, its functionalities are quite different, and it is the first single-use camera with a zoom. Thus, it is interesting to apply the REUSE method on this camera and appreciate the robustness of the method for a new desired artifact.

Adding the zoom function for the viewfinder of the Kodak Zoom, changes the final product, making it different from the existing designs. But the very interesting part is that Kodak designs the viewfinder of the Zoom model based on the Max Outdoor, the one the REUSE method points with the right level of reuse, “design by artifact”. The film holder is identified with the three stages of the method. It is the same chosen by Kodak to equip the Zoom model. For the shutter, the method does not find any existing similar solution. The solution chosen by Kodak is completely different from the other models. The interest of the method for this module is to point the part of the design that designers have to focus on.

5. CONCLUSION

The REUSE method for the knowledge reuse of design information has been introduced in this study with the
three main stages presented and detailed. A case study has been performed and analysis to identify the usefulness of this approach for process design development. This method is sufficiently general to extend it to the design of every product. Finally, this approach allows one to “justify the design”. Traceability should be a huge step in the future by not only tracing the manufacturing but also tracing its origin through the design.

Future works could also include physical connections between a module and its environment. Furthermore, the repository is not always structured by a generic function name; future research will integrate an ontological model to find a module by the functional link and avoid the problem of interpretation by the user [28]. Furthermore, the next step of this research will be the extension of this framework to develop the product aspect and integrate the behavior of the existing products [29].

ACKNOWLEDGMENTS

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REFERENCES


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