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Kansei Engineering over Multiple Product Evolution Cycles: An Integrated Approach

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Abstract

When seeking new opportunities and markets, change is an inevitable reality which product development teams must embrace to maintain product relevance and competitiveness. In fact, one can observe many examples on the market of products and their constituent features evolving over time. This is done not only to meet changing requirements, but also different users' perceptions and subsequently emotions; which may change according to their respective markets. As product lifecycles are getting shorter, it becomes imperative to consider change strategies and product evolution in order to deliver the required product capabilities to targeted markets at specific times. This research proposes a Kansei engineering and integrated approach to support product evolution over multiple cycles. This approach has been applied to the design of a camera enclosure with the results of this study presented.

Peer-review under responsibility of the scientific committee of the CIRP Design Conference 2019

Keywords: Product Development; Design for Emotions; Product Evolution;

1. Introduction

Consumers own many products and stimulating their purchasing behaviour is challenging. A market-in approach to develop products to consider the customers' actual wants and needs enhances the likely-hood of stimulating purchasing behaviour. Many industrial organisations traditionally use a product-out development philosophy which is a product constraint driven design approach [1]. Such an approach advocates for a product to be designed based on technologies and needs which are developed and perceived within the organisation or as part of the organisation's strategy. This is done without giving attention to the customers' actual wants and needs. Such organisations may feel that this is their most suitable approach in tackling their product development; in fact, many innovations have emerged from this approach [2]. It may be criticised that this approach may leave the organisation vulnerable to competition especially as the market matures.

On the other hand, an organisation which employs a market-in approach will lead to the development of a product that fits customer's requirements, including customer's feelings and emotions [2]. Therefore, one can say that the manner we design and engineer our products is facing significant changes in order to meet the societal requirements of satisfying the customer's wants and needs to include their feelings and emotions.

1.1. Kansei engineering

New technology is being developed to enable the realisation of products which considers the user's Kansei [2]. Kansei engineering (KE) is a human-oriented product development technique which primarily tackles satisfying the user's Kansei. Harada described Kansei as an implicit higher function of the brain involved in the creation of intuitive reactions to external stimuli [3,4]. The reaction to such stimuli starts from sensorial input leading to psychological cognition of perception, judgment and memory. Schütte et al. [5] describe KE as being based upon subjective estimations of products and their properties which ultimately helps users express their demands on products including those that they may not be aware of.

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1.1. Challenges of product evolution

That said, when seeking new opportunities and markets, change is an inevitable reality which product development teams must embrace to maintain product relevance and competitiveness. In fact, one can observe many examples on the market of products and their constituent features evolving over time. This is done not only to meet changing requirements, but also different users' perceptions and subsequently emotions; which may change according to their respective markets.

Different markets may need to be targeted using a different Kansei approach as can be described in the following example where a different target market has an effect on the design of a hand drill. Figure 1 shows a comparison of differences in hand drill designs targeted to different markets. It can be observed that the hand drills targeted to professional and semi-professional markets make use of a simpler and less rounded overall form with the use of larger and more rounded grips. Furthermore, these drills include metallic chucks and components which gives the impression of increased robustness. In the case of the second brand, colour was also used to differentiate between the market segments. Therefore, if it is envisaged that a product's target market is going to evolve over time, for example from a professional to a consumer market, one has to understand which features elicit a customer's perception of said product.

Further to these challenges, one has to also consider how product lifecycles are continuously getting shorter. This makes it imperative to consider change strategies and product evolution in order to deliver the required product capabilities to targeted markets at specific times.

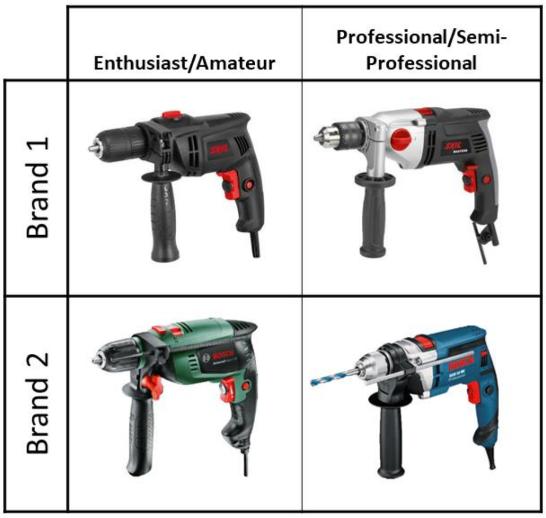

Figure 1: Comparison of drill design according to their target market.

1.1. Research aim

The aim of this paper therefore presents an approach for implementing KE over multiple product evolution cycles. This approach is presented in Section 3 of this paper. In order to provide the required background literature and underlying theory, Section 2 provides an overview of the different Kansei approaches that may be employed and the manner they have been utilised in a number of case studies. It must be noted that KE was initially applied to consumer products, particularly those which are mass produced [6,7]. Despite this fact, KE has already been applied to non-consumer products [7-9]. The case study on which our approach has been implemented is in fact a camera for professional and industrial use. This case study is further detailed in Section 4, and the results of the evaluation of this study are presented in Section 5.

2. Literature review & background theory

2.1. Kansei engineering approaches

The implementation of KE involves steps utilising tools from various disciplines namely marketing, psychology and statistics to name a few. Studies involve both quantitative and qualitative research whereby focus groups, self-support systems and ethnographic techniques are possible means for data collection. However, the main focus revolves around the emotional aspect of the consumer's experience with the products and product concepts. Lokman [3] identified eight types of KE, and are outlined below.

- Type I: Category Classification
- Type II: Kansei Engineering System
- Type III: Kansei Engineering Modelling
- Type IV: Hybrid Kansei Engineering
- Type V: Virtual Kansei Engineering
- Type VI: Collaborative Kansei Engineering
- Type VII: Concurrent Kansei Engineering
- Type VIII: Rough Sets Kansei Engineering

The organisation and Kansei engineer's objectives or assessment strategies determine which type is used in the implementation [3]. A model as shown in Figure 2 was proposed by Schütte and organises the KE procedure in a few steps. This model encompasses the different types of KE. The principle behind this model is to view the product from the semantic structure and physical structure [10].

The semantic space was postulated by Osgood et al. [11] and has been applied to KE as a means to describe and measure a product's affective response. The semantic space is defined as a vector space constructed of a number of product descriptive words termed Kansei words. The definition of the semantic space commences with the collection of as many Kansei words as possible. These words may be collected from various sources such as product literature, experts, experienced users and designers.

If important Kansei words are not collected and selected the results of the Kansei study may be invalid. It is for this reason that more words are collected than necessary [12]. The next task is then for the product designer to manipulate product form features in order to produce a specific style, which satisfies the users' expectations and their affective responses.

In KE a cause and effect relationship between product form features and consumers affective responses is assumed [13].

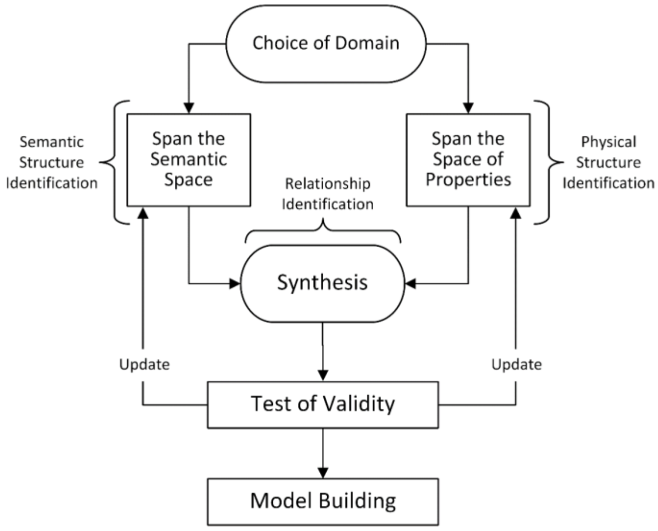

Figure 2: Unified proposed model by Schütte [10]

The three established techniques used to collect and select product properties are manual collection and selection; using quality tools in product development; collection and selection using focus group data.

Schütte [10] also proposed a model to identify the relevant product properties. This model is particularly interesting as it gives room to innovation as the space of properties is not limited to the collection of existing product samples but also includes properties generated from new concepts and properties derived from the company image.

The final task is then to establish a relationship between space of properties and the semantic space. A designer may choose to use any of the techniques exclusively or combined to find the best compromise for the specific product design requirements [14].

2.2. Application of Kansei engineering approaches

A prominent case study discussed in KE literature is the application of KE Type I to the design of various aspects of the Mazda Miata vehicle. The success of the sports car is attributed to the appropriate recognition of the users' need to feel at one with their vehicle. The use of KE enabled the design team to recognise this need and to appropriately design aspects of the vehicle to convey such a feeling [6].

Within an industrial engineering scenario Huang et al. [9], applied KE to the form design of an injection moulding machine. The study included examining the form of injection moulding machine to identify the discreet product form features which make up their design. Category classification was applied to collect and organise the Kansei words. A questionnaire was carried out to find the relationship between the Kansei words and the product form features.

Al-Magro et al. [8] applied KE to the design of an industrial electronics enclosure. Their work included analysing the current design of the enclosure and identified that, despite a product may be robust from an objective point of view, it may not be perceived as so. Therefore, highlighting the relevance of KE to such a product.

2.3. Kansei in concurrent engineering

Andreassen and Hein [15] explain that integrated product development (IPD) is a model of how a product development team organises itself and its design activities to achieve concurrent engineering objectives. A product development team's goal is to generate business and the main task categories required to do so are marketing, product design and manufacturing.

Figure 3 therefore illustrates how this research perceives the conventional KE approach within an IPD context.

IPD calls for a multidisciplinary approach to product development which includes the three main tasks highlighted to be carried out concurrently and for a controlled interplay between product development projects [15].

As a new product development cycle starts, at t=0 and at t=0+x, KE is utilised to determine the domain of the new product, and identify a suitable semantic space and space of product properties.

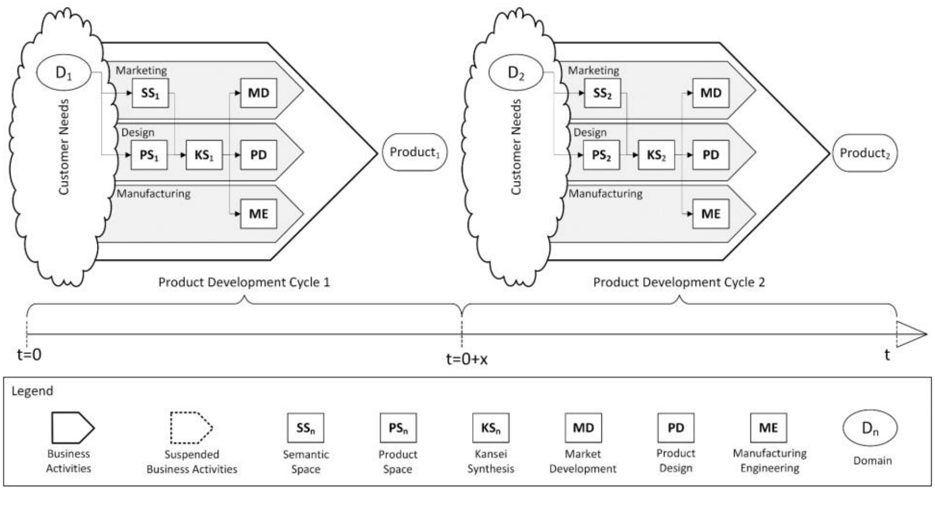

Figure 3: Kansei engineering applied within an IPD context.

If the proceeding product (denoted as $Product_2$) is making use of any carry over components from product 1, then there may be a limit to the changes which may be made to the new product in order to tackle particular user perceptions.

2.4. Research gap

Therefore, the authors recognise the need to implement kansei engineering whilst considering the various evolutionary product develop requirements. From literature reviewed, there is currently no approach which advocates or prescribes a solution to this problem. The hypothesis of this research is that when a product's target market changes over time as part of the product development strategy; an IPD approach to KE will facilitate product evolution. The following section describes a solution which is hereby being proposed to address this research gap.

3. Solution

For many of these tools, good quality data is required to collect and select product attributes. One must be sensitive to the resource requirements for such tools. Furthermore, the designer must recognise that given their resource constraints, manual collection and selection of product attributes may be a cost effective Kansei approach. Manual selection and collection is done by relying on the designer's experience and intuition. The quality of the result depends on factors like the designer's experience, the company structure or the product's maturity [5].

3.1. Kansei engineering over multiple product evolution cycles

The principle behind the proposed solution is to concurrently carry out the KE procedure for the current and evolved product. This is done to enable the understanding of how the product properties affect the users' perception of the respective market segments and subsequently understand how the product is expected to evolve. Figure 4 illustrates the proposed solution.

Once the KE procedure for the current and future product is carried out, the results obtained are used to design the current product whilst keeping in mind future requirements. This assists the designers in taking design decisions such that the risk associated with product evolution is reduced. The decisions taken are also influenced by the manufacturing strategy which would also cater for the product evolution.

3.1. Domain

This research proposes that the choice of domain for both the current and future product evolutions is decided as early as possible in the product development cycle. This decision would have a great impact on both the semantic space and space of product properties. As typically done in the standard KE approach, and as explained by Lokman [3], domain selection can either be done by using market analysis techniques or by segmentation of target markets.

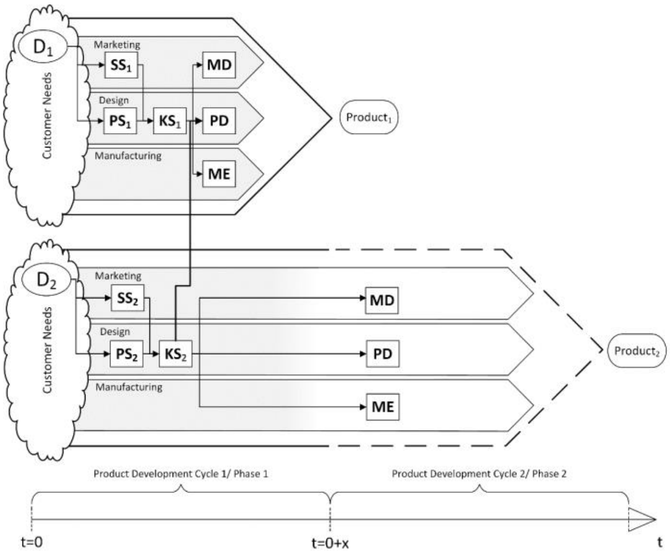

Figure 4: Proposed model for Kansei engineering with product evolution.

This also applies when deciding the domain of the current and evolved product. It is to be determined whether KE should be based on existing products or simply base the product design of a new concept. In theory, different approaches can be harnessed since none of the approaches are superior or inferior to another. In general, the choice of the domain can be based upon the existing product available on the markets [3].

3.2. Semantic space

The semantic space of the current and future product evolutions is defined. Kansei words for the product domains are collected and selected. Interactions between the semantic spaces are assessed. This includes identifying common and conflicting Kansei words between the semantic spaces.

3.3. Space of product properties

Similarly, the product properties for both the current and evolving product are identified. This is done by collecting product samples and analysing their structure.

4. Case study

4.1. Product development scenario

The design of the form of a high-speed camera for use within a business or professional context is being studied. This particular case study is of interest as it is envisaged that its requirements will evolve over a number of years, since the market segment, which is being targeted, is subject to change. Two market segments were identified. A product targeted towards scientific users who seek to capture high speed phenomena will initially be designed. It is planned to evolve the design into a camera targeted towards media production users who seek to capture high-speed imagery for entertainment purposes.

4.2. Scope

A research study, employing the solution proposed in Section 3, is being conducted in order to understand the impact of various design features on the above-mentioned scenario. The data will serve to guide the design team to produce a design, which would satisfy both functional and form requirements of the camera. The study covers the visual Kansei of the camera.

4.3. Semantic space

A number of Kansei words were collected from various media sources including product information web pages and product reviews. To facilitate the process of collection, text analysis tools and data mining tools which indicate the adjectives contained in the media sources, were used. The original list contained around 100 words, this was reduced using manual methods. Table 1 lists examples from the collection of Kansei words. The Kansei words have been organised according to their commonality, distinction and conflict within the different market segments.

Table 1: Example of collected Kansei words.

Common	Distinct	Conflicting
Advanced	Industrial [s]	Non-Traditional [s]
Compact	Innovative [s]	Traditional [m]
Flexible	Ergonomic [m]	
Intuitive	Familiar [m]	
Portable	Well-Balanced [m]	
Professional		
Robust		
Rugged		
Versatile		

The Kansei words for the initial target market (scientific) are denoted by [s] and those for the evolved target market (media production) are denoted by [m]. The number of Kansei words in common between the two market segments exceeds the distinct and conflicting Kansei words, this is indicative that the Kansei of the market segments have a similar semantic structure. The identified primary Kansei words pairs used in this study were Professional-Amateur, Innovative-Derivative and Robust-Fragile.

4.4. Space of properties

A study was carried out to identify the most relevant product form features. A total of 18 camera samples, from both market segments were analysed. A summary excerpt of these product form features is shown in Figure 5. The features were selected according to how profoundly they affect the visual characteristics of the products. The selection was done from the designer's perspective.

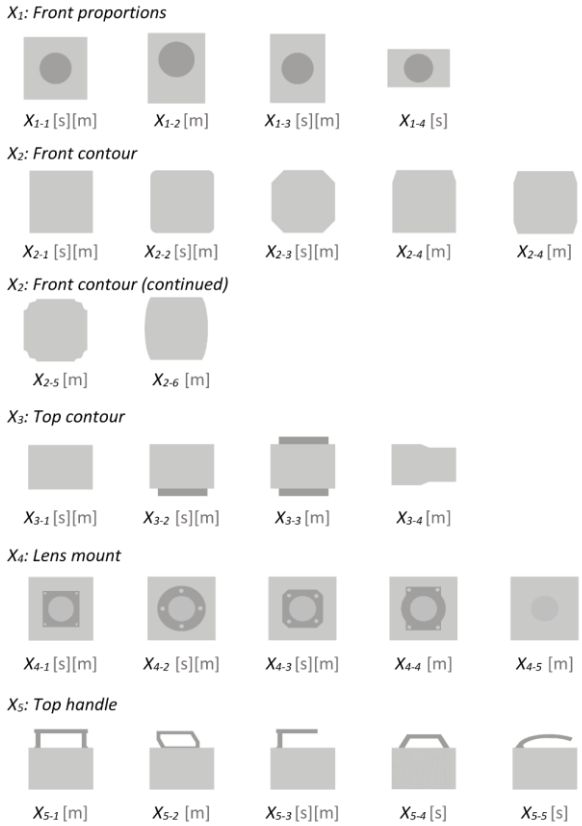

Figure 5: Discrete product form features derived from analysing product samples

The next step of the approach was to combine these features into a total product. Total product refers to a complete product which is made up from the sub-product form features in order to achieve its visual characteristics, refer to Figure 6.

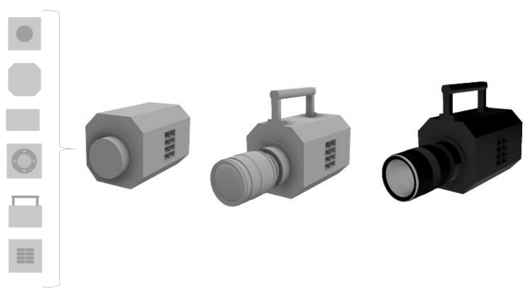

Figure 6: Composition of product form features into a total product.

In order to outline a set of visually distinct total products as shown in Figure 7, three combinations of the underlying features were selected.

Figure 7: Camera designs selected for Kansei survey.

The intent is not to utilise all the product form features which were collected in the previous step but rather to have a set of products which are visually different from each other to represent the evolution of this product. As will be discussed in Section 5, the products had to show the effects of different colours, handles and forms on the users' perception of the camera. In order to do so, the three selected designs were obtained from what is currently available on the market within the domains selected.

5. Evaluation & results

A survey was conducted in order to understand the impact that camera attachments and colour have on the impression the representations create on prospective buyers. 70 respondents participated in the survey. The respondents were selected under a number of categories ranging from consumer to professional usage of camera devices. The survey presented the respondents with the three images indicated in Figure 7 as well as two sets of alternatives presenting the cameras without attachments and without colour, making a total of nine images. The respondents were asked to rate the designs according to how they perceive them on 5-point semantic differential scales with the primary Kansei words indicated in section 4.3.

6. Evaluation results

Kansei averages were assessed to understand how the designs compare to each other. Media production users regarded design C as the most robust looking. Whilst scientific users regarded design A as most robust. On the other hand, both user groups considered design B to be the most innovative, but also the least professional and robust. Therefore, within the scope of this case study which is to target a scientific market with a professional camera, then design C is the most appropriate. Since in the future the target market will be that of media production users who require a robust product, then the form design would have to evolve towards design A. This has an implication on how the main internal components are designed since they must fit within both designs.

7. Conclusion

The research work presented in this paper contributes to an integrated approach which extends this concept to cover multiple product evolutions. As product lifecycles are getting shorter, it becomes imperative to consider change strategies and product evolution in order to deliver the required product capabilities to targeted markets at specific times. This approach has been applied to the design of a camera enclosure which supported the researchers in identifying product properties which had an effect on the Kansei of the designed artefact. This approach is innovative as it is unique in addressing product evolution, and also makes use of an integrated approach which considers manufacturing constraints on the evolving product design. Future research work would include structuring the semantic space further into multi-level Kansei words with the use of tools such as an affinity diagram. A further study would also include more properties such as texture and surface finish and a design of experiments to determine exactly which product properties gives which Kansei responses.

Acknowledgments

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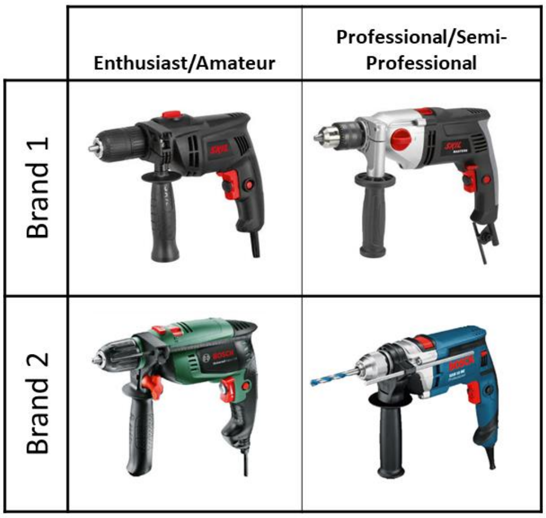

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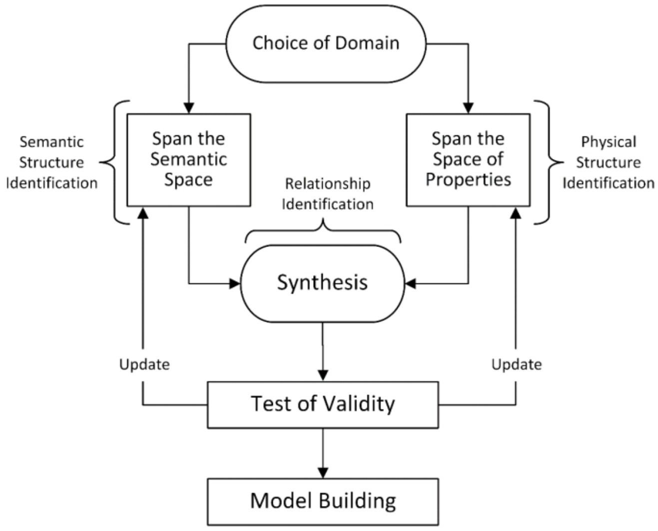

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A prominent case study discussed in KE literature is the application of KE Type I to the design of various aspects of the Mazda Miata vehicle. The success of the sports car is attributed to the appropriate recognition of the users' need to feel at one with their vehicle. The use of KE enabled the design team to recognise this need and to appropriately design aspects of the vehicle to convey such a feeling [6].

Within an industrial engineering scenario Huang et al. [9], applied KE to the form design of an injection moulding machine. The study included examining the form of injection moulding machine to identify the discreet product form features which make up their design. Category classification was applied to collect and organise the Kansei words. A questionnaire was carried out to find the relationship between the Kansei words and the product form features.

Al-Magro et al. [8] applied KE to the design of an industrial electronics enclosure. Their work included analysing the current design of the enclosure and identified that, despite a product may be robust from an objective point of view, it may not be perceived as so. Therefore, highlighting the relevance of KE to such a product.

2.3. Kansei in concurrent engineering

Andreassen and Hein [15] explain that integrated product development (IPD) is a model of how a product development team organises itself and its design activities to achieve concurrent engineering objectives. A product development team's goal is to generate business and the main task categories required to do so are marketing, product design and manufacturing.

Figure 3 therefore illustrates how this research perceives the conventional KE approach within an IPD context.

IPD calls for a multidisciplinary approach to product development which includes the three main tasks highlighted to be carried out concurrently and for a controlled interplay between product development projects [15].

As a new product development cycle starts, at t=0 and at t=0+x, KE is utilised to determine the domain of the new product, and identify a suitable semantic space and space of product properties.

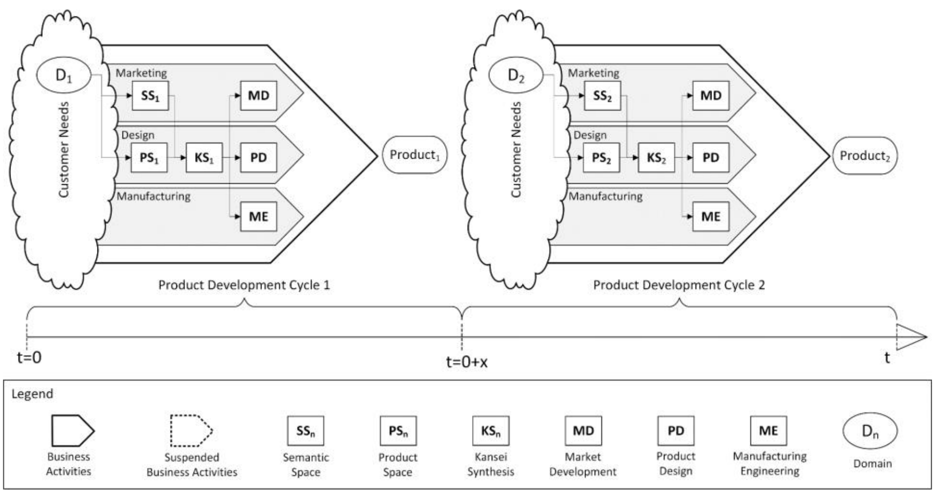

Figure 3: Kansei engineering applied within an IPD context.

If the proceeding product (denoted as $Product_2$) is making use of any carry over components from product 1, then there may be a limit to the changes which may be made to the new product in order to tackle particular user perceptions.

2.4. Research gap

Therefore, the authors recognise the need to implement kansei engineering whilst considering the various evolutionary product develop requirements. From literature reviewed, there is currently no approach which advocates or prescribes a solution to this problem. The hypothesis of this research is that when a product's target market changes over time as part of the product development strategy; an IPD approach to KE will facilitate product evolution. The following section describes a solution which is hereby being proposed to address this research gap.

3. Solution

For many of these tools, good quality data is required to collect and select product attributes. One must be sensitive to the resource requirements for such tools. Furthermore, the designer must recognise that given their resource constraints, manual collection and selection of product attributes may be a cost effective Kansei approach. Manual selection and collection is done by relying on the designer's experience and intuition. The quality of the result depends on factors like the designer's experience, the company structure or the product's maturity [5].

3.1. Kansei engineering over multiple product evolution cycles

The principle behind the proposed solution is to concurrently carry out the KE procedure for the current and evolved product. This is done to enable the understanding of how the product properties affect the users' perception of the respective market segments and subsequently understand how the product is expected to evolve. Figure 4 illustrates the proposed solution.

Once the KE procedure for the current and future product is carried out, the results obtained are used to design the current product whilst keeping in mind future requirements. This assists the designers in taking design decisions such that the risk associated with product evolution is reduced. The decisions taken are also influenced by the manufacturing strategy which would also cater for the product evolution.

3.1. Domain

This research proposes that the choice of domain for both the current and future product evolutions is decided as early as possible in the product development cycle. This decision would have a great impact on both the semantic space and space of product properties. As typically done in the standard KE approach, and as explained by Lokman [3], domain selection can either be done by using market analysis techniques or by segmentation of target markets.

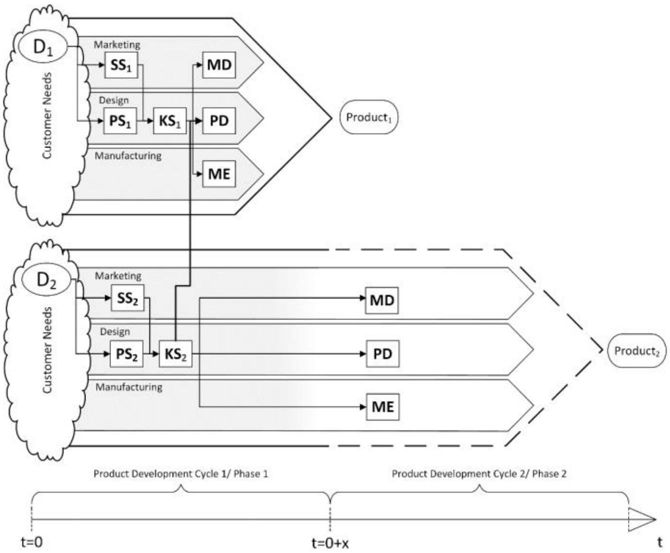

Figure 4: Proposed model for Kansei engineering with product evolution.

This also applies when deciding the domain of the current and evolved product. It is to be determined whether KE should be based on existing products or simply base the product design of a new concept. In theory, different approaches can be harnessed since none of the approaches are superior or inferior to another. In general, the choice of the domain can be based upon the existing product available on the markets [3].

3.2. Semantic space

The semantic space of the current and future product evolutions is defined. Kansei words for the product domains are collected and selected. Interactions between the semantic spaces are assessed. This includes identifying common and conflicting Kansei words between the semantic spaces.

3.3. Space of product properties

Similarly, the product properties for both the current and evolving product are identified. This is done by collecting product samples and analysing their structure.

4. Case study

4.1. Product development scenario

The design of the form of a high-speed camera for use within a business or professional context is being studied. This particular case study is of interest as it is envisaged that its requirements will evolve over a number of years, since the market segment, which is being targeted, is subject to change. Two market segments were identified. A product targeted towards scientific users who seek to capture high speed phenomena will initially be designed. It is planned to evolve the design into a camera targeted towards media production users who seek to capture high-speed imagery for entertainment purposes.

4.2. Scope

A research study, employing the solution proposed in Section 3, is being conducted in order to understand the impact of various design features on the above-mentioned scenario. The data will serve to guide the design team to produce a design, which would satisfy both functional and form requirements of the camera. The study covers the visual Kansei of the camera.

4.3. Semantic space

A number of Kansei words were collected from various media sources including product information web pages and product reviews. To facilitate the process of collection, text analysis tools and data mining tools which indicate the adjectives contained in the media sources, were used. The original list contained around 100 words, this was reduced using manual methods. Table 1 lists examples from the collection of Kansei words. The Kansei words have been organised according to their commonality, distinction and conflict within the different market segments.

Table 1: Example of collected Kansei words.

Common	Distinct	Conflicting
Advanced	Industrial [s]	Non-Traditional [s]
Compact	Innovative [s]	Traditional [m]
Flexible	Ergonomic [m]	
Intuitive	Familiar [m]	
Portable	Well-Balanced [m]	
Professional		
Robust		
Rugged		
Versatile		

The Kansei words for the initial target market (scientific) are denoted by [s] and those for the evolved target market (media production) are denoted by [m]. The number of Kansei words in common between the two market segments exceeds the distinct and conflicting Kansei words, this is indicative that the Kansei of the market segments have a similar semantic structure. The identified primary Kansei words pairs used in this study were Professional-Amateur, Innovative-Derivative and Robust-Fragile.

4.4. Space of properties

A study was carried out to identify the most relevant product form features. A total of 18 camera samples, from both market segments were analysed. A summary excerpt of these product form features is shown in Figure 5. The features were selected according to how profoundly they affect the visual characteristics of the products. The selection was done from the designer's perspective.

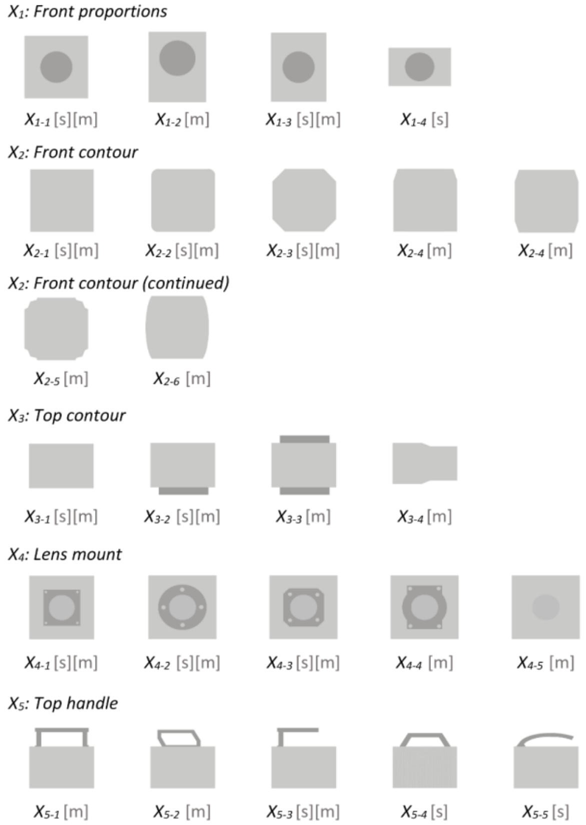

Figure 5: Discrete product form features derived from analysing product samples

The next step of the approach was to combine these features into a total product. Total product refers to a complete product which is made up from the sub-product form features in order to achieve its visual characteristics, refer to Figure 6.

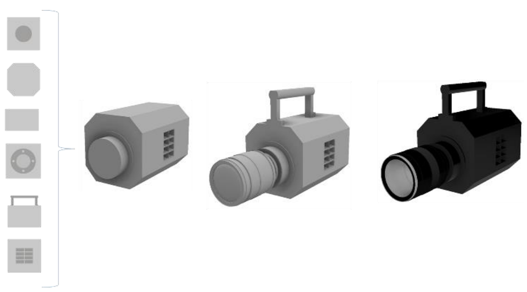

Figure 6: Composition of product form features into a total product.

In order to outline a set of visually distinct total products as shown in Figure 7, three combinations of the underlying features were selected.

Figure 7: Camera designs selected for Kansei survey.

The intent is not to utilise all the product form features which were collected in the previous step but rather to have a set of products which are visually different from each other to represent the evolution of this product. As will be discussed in Section 5, the products had to show the effects of different colours, handles and forms on the users' perception of the camera. In order to do so, the three selected designs were obtained from what is currently available on the market within the domains selected.

5. Evaluation & results

A survey was conducted in order to understand the impact that camera attachments and colour have on the impression the representations create on prospective buyers. 70 respondents participated in the survey. The respondents were selected under a number of categories ranging from consumer to professional usage of camera devices. The survey presented the respondents with the three images indicated in Figure 7 as well as two sets of alternatives presenting the cameras without attachments and without colour, making a total of nine images. The respondents were asked to rate the designs according to how they perceive them on 5-point semantic differential scales with the primary Kansei words indicated in section 4.3.

6. Evaluation results

Kansei averages were assessed to understand how the designs compare to each other. Media production users regarded design C as the most robust looking. Whilst scientific users regarded design A as most robust. On the other hand, both user groups considered design B to be the most innovative, but also the least professional and robust. Therefore, within the scope of this case study which is to target a scientific market with a professional camera, then design C is the most appropriate. Since in the future the target market will be that of media production users who require a robust product, then the form design would have to evolve towards design A. This has an implication on how the main internal components are designed since they must fit within both designs.

7. Conclusion

The research work presented in this paper contributes to an integrated approach which extends this concept to cover multiple product evolutions. As product lifecycles are getting shorter, it becomes imperative to consider change strategies and product evolution in order to deliver the required product capabilities to targeted markets at specific times. This approach has been applied to the design of a camera enclosure which supported the researchers in identifying product properties which had an effect on the Kansei of the designed artefact. This approach is innovative as it is unique in addressing product evolution, and also makes use of an integrated approach which considers manufacturing constraints on the evolving product design. Future research work would include structuring the semantic space further into multi-level Kansei words with the use of tools such as an affinity diagram. A further study would also include more properties such as texture and surface finish and a design of experiments to determine exactly which product properties gives which Kansei responses.

Acknowledgments

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