RGC Ref. No.:
UGC/FDS14/E02/15
_____
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:	1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.* 2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. **Project Title**

    Relative Attribute Based Configurator Design for Mass Customization
    _____

    _____

2. **Investigator(s) And Academic Department(s) / Unit(s) Involved**

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	WANG, Yue / Assistant Professor	Department of Supply Chain and Information Management / The Hang Seng University of Hong Kong
Co-Investigator(s)	MO, Yiu-wing / Assistant Professor	Department of Supply Chain and Information Management / The Hang Seng University of Hong Kong

3. **Project Duration**

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2016		
Project Completion Date	31/12/2017	30/06/2018	11/10/2017
Duration *(in month)*	24	30	11/10/2017
Deadline for Submission of Completion Report	31/12/2018	30/06/2019	11/10/2017

Part B: The Final Report

5.   Project Objectives

5.1   Objectives as per original application

1. To develop a more user-friendly configurator system to facilitate the choice navigation process for mass customisation.
2. To generate a description of customers' relative attribute preferences towards products.
3. To develop a relative attribute–based configurator to facilitate choice navigation for customers.
4. To study the scope of application for the proposed approach.

5.2   Revised objectives

Date of approval from the RGC: N/A
_____

Reasons for the change:
_____

_____

1.

2.

3. ....

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

- The first objective of this project is to develop a more user-friendly configurator system to facilitate the choice navigation process for mass customization. It is also the general objective of the whole project and on top of the other three objectives. To summary, we made great effort along this direction and have achieved interesting findings on new configuration mechanism design. One of the key issues of current configurators is that user experience is not fully considered in the design of configuration interface. We developed a new configuration approach which can take customer needs in layman language as the input and transform the needs into tangible product configurations (Please check the first and third journal papers in part C, J1 and J3). This could reduce the semantic gap between customer needs and companies' offering and greatly reduce the requirement of expertise from users when using configurators. In addition, we proposed the relative preferences-based configurator (The second journal paper, J2). Studies in psychology show that it is much easier for people to indicate their relative preferences to a reference product. Thus, the idea of this new breed of configurators is to help customers identify their relative needs and preferences using the comparative evaluation instead of the direct specifications in traditional configurators. Through these two ways, more user-friendly configurators are developed. Computational experiments show promising results of the method. Thus, objective 1 is realized.

- Objective 2 serves as the basis to develop the more user-friendly configuration system. We investigated different ways of generating description of customer preferences. Firstly, we use a set of ordered attribute pair to indicate customers' relative preferences towards the attribute choices (Details in J2). The ordered set can be used to develop the relative attribute-based configurator. Secondly, we further extend the ordered set to natural language (Details in J3). This is a more natural way of expressing the needs. Customers don't need to make evaluation and selection about the choices to indicate their preferences. It is a more user-friendly means to describe customers preferences. This natural language description is further processed using machine learning techniques to realize the first objective. This objective is also fully achieved.

- Objective 3 is under objective 1 and is achieved as well. We collected a set of ordered attribute pairs through empirical experiment. The ordered pairs indicate customers preferences towards the product. Then we leverage the ordered pair to build a relative attribute-based configurator using nonlinear programming and optimization. Details can be found in J3.

- We conducted a series of empirical study to explore the scope of application of the new configurator design. Products can be categorized to hedonic and utilitarian types as indicated in marketing research. We studied how customer make decision under various configuration environment through empirical experiments for typical hedonic products (such as watch, t-shirt, and food) and utilitarian products (such as laptop, and bicycle). We further studied what if default options, best seller options are provided and what if multiple choices can be selected during configuration process. Some interesting results can be found from conference paper C1, C3, C5 and C7. This objective is also achieved.

5.4   Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	Addressed *(please tick)*	Percentage Achieved *(please estimate)*
1. To develop a more user-friendly configurator system to facilitate the choice navigation process for mass customisation	✓	100%
2. To generate a description of customers' relative attribute preferences towards products	✓	100%
3. To develop a relative attribute–based configurator to facilitate choice navigation for customers	✓	100%
4. To study the scope of application for the proposed approach	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

- New ways of bridging semantic gap between customer needs and product configurations using machine learning approach

The elicitation of customer needs (CNs) is critical for product design. However, these needs are often expressed in natural language and not in the form of well-defined specifications, causing a semantic gap in the design process. This difficulty hinders the configuration process in customized product design. We propose a machine learning mechanism to automatically bridge the semantic gap (**see conference paper, C2**). This bridging task is considered as a classification problem, with CNs being the class. The mapping function from product technical specifications to CNs is learned from training data by using a support vector machine and decision tree classifier. Experiment results showed that the proposed method can achieve very high mapping accuracy. In addition, the massive amount of product review text could provide valuable insights for product development. We also adopted Bi-directional LSTM Recurrent Neural Network to extract product review keywords from product review text (**Conference paper, C4**). Based on the keywords, a mapping is learnt to transform the keywords to product configurations (**Journal paper, J1**). To facilitate customers' decision-making process when using configurators, we proposed relative preferences-based configurator mechanism (**Journal paper, J2**). All of these research outputs can shield product development teams from the tedious labour of linking CNs to product variants, and thus improve the efficiency of needs elicitation and product configuration.

- Configuring product using natural language

Customer needs are mostly expressed in natural language. It would be more convenient if configurators could take natural languages as the input and transform them into tangible product specifications. By leveraging natural language processing techniques, we made some exploration along this direction. Specifically, we encode the natural language needs with word embedding through three operations, i.e., pointwise average, max-pooling and the concatenation of these two. The needs are thus encoded as a vector and inputted to classifiers to be transformed to product configurations (**Conference paper C6**). We also applied hierarchical attention network to map the general natural language needs to product configurations (**Journal paper, J3**). The key idea is to differentiate the words in the needs text. The ones which are more relevant to customer needs are assigned bigger weight. Thus, the results are even better in terms of precision and recall of the configuration recommendation.

- The effect of configurator design on customer decision making

Product configurators serve as a critical tool to bridge customer needs and companies' offerings. Thus, an effective and efficient configurator should consider how people's decision making process is influenced by the design of configurators. Motivated by findings in the areas of consumer behavior and psychology, we examine how people make decisions under different configuration context, such as configurator with default options (**Conference paper C1 and C5**), best seller information (**C7**), and multiple choices (**C3**). Specifically, we investigate how the effect correlates with factors, including product type, customers' degree of expertise, motivation to process information etc. Empirical experiments were designed and conducted to test the corresponding hypotheses. The findings could provide useful guideline to improve the interface of product configurators.

6.2 Potential for further development of the research and the proposed course of action
(Maximum half a page)

We envisage two promising research directions in the area of engineering design. Firstly, user-centric design has gained much attention as customers are more empowered. Thus, it is critical to improve the user interface of existing design platform. However, only focusing on the engineering solution part is not enough. We should also consider the user interface design from customer side. Specifically, how do people make decision, how various factors interact to affect consumer decision making, etc.? The research methodologies and findings form marketing, psychology, economics are indispensable to conduct research towards this direction.

Furthermore, a massive amount of product-relevant data can be extracted from e-commerce websites, including product reviews and product metadata. Data-driven approaches are becoming popular in engineering design. This could provide great opportunity to exploit the massive online product-relevant data to solve the problems in design, such as information retrieval, design function extraction and product feature priority. In addition, existing approaches in natural language processing, deep learning, etc. have achieved surprisingly good results. This provides a great opportunity to use data-driven approaches to advance product configurator design and relevant research.

7. Layman's Summary
(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

Configurators serve as a critical enabling toolkit for customers to co-create the product. A traditional product configurator consists of a set of predefined components or attributes. It takes customer's choices of the components as input and the total specifications will form the desired product variant. However, customers may not have the necessary expertise about the product which they are unfamiliar with. They can only express their actual perceptual intents and needs in a vague and imprecise language. There is a great need for a more user-friendly configurator design method to improve the choice navigation procedure. This proposal addresses the challenge by efficiently bridging the gap between product design specifications and the intent of customers. We deploy machine learning approaches to break the barrier in these two domains by learning a mapping function from customers' choices data. A new relative attribute-based configurator was built. In addition, we further extend the application scope of traditional configurators by allowing customers to express their needs in natural language. Computational and empirical experiment results show great potential for the new breeds of configurators to be applied in industry. They shield customers from the confusion and perplexity encountered in traditional configurators.

Part C: Research Output

8. **Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project**
   (Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) *(denote the corresponding author with an asterisk*)*	Title and Journal / Book *(with the volume, pages and other necessary publishing details specified)*	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
Year of Publication	Year of Acceptance *(For paper accepted but not yet published)*	Under Review	Under Preparation *(optional)*						
2018				Wang, Y., D. Mo and M. M. Tseng*	Mapping Customer Needs to Design Parameters in the Front End of Product Design by Applying Deep Learning, CIRP Annals-Manufacturing Technology, 67(1): 145-148	No	Yes	Yes	Yes
	2019			Wang, Y.*, D. Mo and M. M. Tseng	Relative Preference-based Product Configurator Design, Procedia CIRP	No	Yes	Yes	Yes
	2019			Wang, Y.*, and Zhao Raymond	Needs-based Product Configurator Design for Mass Customization Using Hierarchical Attention Network, IEEE Transactions on Automation Science and Engineering	No	Yes	No (under double blind review now. Will acknowledge RGC if it is accepted)	No

			2019	Wang, Y.*, and Li, Xiang	Configuring Products by Natural Language	No	No	No	No

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered
(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC *(indicate the year ending of the relevant progress report)*	Attached to this Report *(Yes or No)*	Acknowledged the Support of RGC *(Yes or No)*	Accessible from the institutional repository *(Yes or No)*
12/2016/ Bali	How Reference Options Affect Customer Decisions in Product Configuration	2016 IEEE conference on Industrial Engineering and Engineering Management	2016	Yes	Yes	Yes
08/2017/ Vancouver	Bridging the Semantic Gap for Customer Needs Elicitation: A Machine Learning Perspective	21st International Conference on Engineering Design	2017	Yes	Yes	Yes
12/2017/ Singapore	How Do Flexible Options Affect Customer Decision Making in an Online Configurator System?	2017 IEEE International Conference on Industrial Engineering and Engineering Management	2017	Yes	Yes	Yes
12/2017/ Singapore	Keyword Extraction from Online Product Reviews Based on Bi-directional LSTM Recurrent Neural Network	2017 IEEE International Conference on Industrial Engineering and Engineering Management	2017	Yes	Yes	Yes
09/2018/ Graz	The Effect of Default Options on Consumer Decisions in the Product Configuration Process	The 20th Configuration Workshop	No	Yes	Yes	Yes

12/2018/ Hong Kong	Mapping Customer Needs in Natural Language to Product Specifications by Using Word Embeddings	The 19th Asia Pacific Industrial Engineering and Management Systems Conference	No	Yes	Yes	Yes
12/2018/ Bangkok	Observational Learning in the Product Configuration Process: An Empirical Study	2018 IEEE International Conference on Industrial Engineering and Engineering Management	No	Yes	Yes	Yes

10. **Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning**
(Please elaborate)

SCM4304 Honours Project is a core elective for students in SCM department. During the past two years, several groups conducted the project relevant to this research. Typical research questions include the effect of default options, best seller information and number of choices on consumer decision making during product configuration process. The expected outcome could provide some insights about configurators development. Students also benefit from the research experience partially supported by the FDS project.

11. **Student(s) Trained**
(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
N/A			

12. **Other Impact**
(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

During the project period, we collaborate with Dongguan Polytechnic University in China on some research topics. E-commerce industry is well developed in China. It is relative

easier to capture customer needs and opinion information from different e-commerce website. The researchers in Dongguan Polytechnic University help capture raw data and pre-process the raw data. And then the whole team develops algorithms on mapping customer needs to product specifications. We will collaborate with colleagues in China and leverage on the abundant data on major e-commerce website to carry out the research.

13. Public Access Of Completion Report
(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
N/A	

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COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

<u>**Completion Report - Attachment**</u>
(for completed projects only)

RGC Ref. No.: UGC/FDS14/E02/15

Principal Investigator: Dr Yue Wang

Project Title: Relative Attribute Based Configurator Design for Mass Customization

<u>**Statistics on Research Outputs**</u>

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (Please specify)
No. of outputs arising directly from this research project [or conference]	1 published, 1 accepted, 1 under review, and 1 in preparation.	7			