RGC Ref. No.:
UGC/FDS14/E06/18
(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

Generalised Needs-based Product Configurator Design

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Yue Wang / Associate Professor	Department of Supply Chain and Information Management / The Hang Seng University of Hong Kong
Co-Investigator(s)	Daniel Mo / Associate Professor	Department of Supply Chain and Information Management / The Hang Seng University of Hong Kong
Others		

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2019		
Project Completion Date	31/12/2020	30/06/2021	15/10/2020

Duration *(in month)*	24	30	15/10/2020
Deadline for Submission of Completion Report	31/12/2021	30/06/2022	15/10/2020

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. to develop a theoretical foundation and methodology for generalised needs-based product configurators
2. to build an indirect mapping from product review, which can be extracted from e-commerce websites in sufficient amount, to product configuration
3. to adapt the original 'product review-to-product configuration' mapping to 'customer needs-to-product configuration' mapping
4. to develop new assessment methods and conduct a case study to evaluate the approaches

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 theoretical foundation and methodology for generalised needs-based product configurators. It is also the overall objective of the whole project. We made great efforts along this direction and have achieved promising results on needs-based product configurator design. The novel needs-based product configurators could take customer needs in layman language as the input and transform the needs into tangible product configurations (Please check paper J1, J2, J3, and J5 in Part C). Experiments and theoretical analysis show the effectiveness of the proposed approaches. This could reduce the semantic gap between customer needs and companies' offering on customized products. Thus, objective 1 is realized.

Objective 2 aims to build an indirect mapping from product review to product attribute specifications, i.e., the source mapping. Objective 3 is to adapt the original 'product review-to-product configuration' mapping to 'customer needs-to-product configuration' mapping. These two objectives are highly related and thus we would like to elaborate the realization of them together. Needs-based configurators attempt to map customer needs in natural language to product attribute specifications. Data sparsity in customer needs domain is a critical challenge to build the needs-based configurator, as there are no publicly available customer needs data corpus. To solve this problem, we use the massive amount of online product reviews as an intermediary. Using various machine learning methods such as MLP, convolutional neural network and long short-term memory recurrent neural network, we built the source mapping from reviews to product attributes which is the main focus of objective 2. After obtaining the source mapping, we collect a small amount of customer needs text to adapt the source model to the target needs-specifications mapping. We fine-tuned the source mapping network using the small amount of needs text and realize the targe mapping. Relevant papers (J1, J2, and J3) can be found in Part C. In addition, considering deep learning-based methods requires huge amount of data and computational resources to train the model, we also develop a simple and effective word embedding based method to capture customer needs and recommend the satisfactory product (Please check paper J5). Objectives 2 and 3 are fully achieved.

Objective 4 is to develop assessment methods and conduct a case study to evaluate the approaches. We mainly evaluated the proposed approaches using computational experiment and empirical study. The product configuration task is treated as a classification problem. Thus, the assessment methods of precision, recall and F1 score are used in our papers. In addition, we notice that it is more efficient to present a list of items as the recommendation like an information retrieval system than recommending just a single item. To consider the position of the satisfactory item in the recommendation list, we use normalized discounted cumulative gain (nDCG) as the assessment method. Furthermore, we use empirical experiment to evaluate customers' satisfaction for the configuration mechanism. We studied how customer make decision under various configuration environment through empirical experiments for typical hedonic products and utilitarian products.

We further studied whether customers choices are affected by the recommended items which are in the form of default options and best seller options. Some interesting results were reported in the conference paper C1. Furthermore, we also proposed that time perception in the configuration process can be used as an assessment method for the effectiveness of configuration procedure. To the best of our knowledge, this is the first attempt to utilize time as the performance metric for configuration task. Please check the conference paper C2 and the journal paper J6 which is under review. 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 theoretical foundation and methodology for generalised needs-based product configurators	√	100%
2. to build an indirect mapping from product review, which can be extracted from e-commerce websites in sufficient amount, to product configuration	√	100%
3. to adapt the original 'product review-to-product configuration' mapping to 'customer needs-to-product configuration' mapping	√	100%
4. to develop new assessment methods and conduct a case study to evaluate the approaches	√	100%

6. Research Outcome

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

- A user-friendly way to map customer needs in natural language to product attributes specifications (relevant to objective 1, 2, 3 and 4)

One of the key issues of current online configurators is that user experience is not fully considered. Traditionally, customers need to pin down the detailed product specifications using their own knowledge and expertise on the product. Due to the lack of domain knowledge, they may find the configuration process confusing and hard to use. We proposed a more user-friendly way to tackle this issue by allowing customers to input their requirements to the online system using natural language. Promising results were obtained (Relevant papers: J1, J2 and J3). Experiment results show the high precision, recall and DCG results of the product product configuration process.

- Presenting the configuration results using maximal marginal relevance-based approach (relevant to objective 2 and 3)

In configuration process, the customer needs in layman language will be mapped to a series of product attributes specifications. The combination of the specifications forms the potentially satisfactory product for the customers. However, the number of specs combinations may be huge, making it hard for customers to screen all the presented product configurations and find the satisfactory one. We proposed a maximal marginal relevance-based method to present a set of product configurations. This approach ensures a broad coverage of customers' needs by considering not only the relevance of each product to their requirements but also the redundancy in the set of product configurations. Details can be found in journal paper J4.

- A resource-effective configurator for industrial application (relevant to objective 1, 2, 3 and 4)

Our investigation mentioned in the previous point (journal papers, J1, J2 and J3) used deep learning approaches. But they are resources-extensive and require a massive amount of training data and model training time. This makes deep learning methods prohibitive for industrial applications. In another work (J5 in Part C) we showed that the well-designed text embeddings combined with MLP can achieve comparable performance with deep learning-based approaches, yet with higher efficiency and much lower requirement in terms of computational complexity. This could greatly facilitate its application in industry.

- Assessment of configuration process using time perception (relevant to objective 4)

An effective and efficient configurator should consider not only the effectiveness of recommendation, but also customers satisfaction and experience. Psychology and information retrieval researchers have acknowledged that time is an important factor in measuring customer satisfaction with decision-making process. Some recent studies have also shown that the subjective perception of time is an even more relevant measure of customer satisfaction. Inspired by these finding, we propose to use time perception to assess product configuration process. Empirical experiments are designed to answer the relevant research questions. The experiment's results show that two factors, namely the difficulty of the task and the customers' motivation to process information, both significantly affect customers' perceptions of time. We also find that customers' perceptions of time are significantly correlated with their satisfaction with the configured products, and that perceived time is moderately correlated with satisfaction with the configuration process. Relevant research output can be found in the conference paper C2 and Journal paper J6 (under review).

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

We reported the research outcomes in several top tier journals, such as IEEE Transactions on Industrial Informatics (#1 in industrial engineering). The reviewers thought highly of the needs-based configurator, indicating that the idea is 'delicate and relevant in configuration research by capturing user preferences and needs expressed as much as possible in natural language'. Furthermore, we did identify some future research topics along this direction. The needs-based configurators were developed using machine learning method which usually requires sufficient data to train the model. Furthermore, an existing needs-based configurator cannot be applied to updated products even in the same family, and thus the effort must be repeated to build a new configurator, which incurs additional costs. Therefore, a resource-effective method of building a needs-based configurator is needed. Inspired by the paradigm of pre-training then fine-tuning, as used in machine learning research, we plan to pre-train a general-purpose configurator platform to facilitate the development of needs-based configurators. The platform is not a product-specific configurator but rather a collection of features or knowledges to implement needs-based configurators. Users can fine-tune the knowledge in the configuration platform to derive product-specific configurators, enabling companies to train their configurators with limited machine learning knowledge, data and effort. We have submitted a proposal to study the development of the general needs-based configurator platform as an extension of UGC/FDS14/E06/18.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

Product configurators enable a special product design process wherein the product being customized consists of instances of a set of predefined product attributes. The successful application of product configurators can be seen in companies from various industries, such as Dell, BMW and Nike. This configure-to-order process requires customers to possess the necessary domain knowledge of the product. However, customers may not have the appropriate expertise with unfamiliar products. Due to customers' lack of domain knowledge and unawareness of latent preferences, they may only express needs in vague and imprecise language, instead of using product specifications. Existing configurators are incapable of serving customers in a more user-friendly way. It would be much better if product configurators could understand customer needs and intent through layman's language. In the proposed project, we developed a needs-based configurator to overcome these challenges. We leverage natural language processing and machine learning techniques to interpret ambiguous and probably ill-defined customer needs sentences and map them to well-defined product configurations. Through this process, a more user-friendly product configuration process will be designed. We expect the proposed project to advance the design of product configurators and even lead to a breakthrough in product customization in a larger arena.

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 correspond-ing 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)*	Acknowl-edged 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)*						
	2020			**Yue Wang*, Linkai Luo, and Hai Liu**	**J1:** Bridging the Semantic Gap Between Customer Needs and Design Specifications Using User-Generated Content / *IEEE Transactions on Engineering Management*. doi: 10.1109/TEM.2020.3021698.	**No**	**Yes (Annex I)**	**Yes**	**Yes (https://researchdb.hsu.edu.hk/view/publication/202000253)**
2021				**Yue Wang* and Xiang Li**	**J2:** Mining Product Reviews for Needs-Based Product Configurator Design: A Transfer Learning-Based Approach /*IEEE Transactions on Industrial Informatics*, 17(9), 6192-6199. doi: 10.1109/TII.2020.3043315.	**No**	**Yes (Annex II)**	**Yes**	**Yes (https://researchdb.hsu.edu.hk/view/publication/202100214)**
2021				**Yue Wang*, Xiang Li and Daniel Mo**	**J3:** Knowledge-Empowered Multi-Task Learning to Address the Semantic Gap Between Customer Needs and Design Specifications / *IEEE Transactions on Industrial Informatics*, 17(12), 8397-8405. doi: 10.1109/TII.2021.3067141.	**No**	**Yes (Annex III)**	**Yes**	**Yes (https://researchdb.hsu.edu.hk/view/publication/202100215)**
2021 (online)				**Jack Wu, Yue Wang* and J. Ma**	**J4:** Maximal Marginal Relevance-Based Recommendation for Product Customization / *Enterprise Information Systems*	**No**	**Yes (Annex IV)**	**Yes**	**Yes (https://researchdb.hsu.edu.hk/view/publication/202100216)**

2021 (online)				**Yue Wang*, Xiang Li, Linda Zhang and Daniel Mo**	**J5:** Configuring Products With Natural Language: A Simple Yet Effective Approach Based on Text Embeddings and Multilayer Perceptron / *International Journal of Production Research*	**No**	**Yes (Annex V)**	**Yes**	**Yes (https://researchdb.hsu.edu.hk/view/publication/202100111)**
		2022		**Yue Wang, Daniel Mo and Helen Ma***	**J6:** Perception of time in the online product customization process / under review	**No**	**Yes (Annex VI)**	**Will acknowledge RGC if the paper gets accepted.**	**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)*
12/2019/ Macau	C1: Observational Learning in the Product Configuration Process: The Effect of Information Presentation Format	IEEE Conference on Industrial Engineering and Engineering Management	2019	No	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/201900344)
10/2020/ Toronto, Canada	C2: Perception of Time in the Product Configuration Process: An Empirical Study	IEEE International Conference on Systems, Man, and Cybernetics (SMC)	No	Yes	Yes (Annex VII)	Yes (https://researchdb.hsu.edu.hk/view/publication/202000254)
12/2021/ online	C3: Addressing the Semantic Gap in the Consumer-to-Manufacturer Strategy Using Dual Convolutional Neural Network	IEEE Conference on Industrial Engineering and Engineering Management	No	Yes	Yes (Annex VIII)	Yes (https://researchdb.hsu.edu.hk/view/publication/202100217)

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

The research outcome has contributed to teaching and learning in HSUHK. SCM4304 Honours Project and SCM 4308 Senior Year Project are core electives for students in SCM department in HSUHK. 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.

The research outcome also benefits the teaching of other courses. When teaching the topic of business decision making in the module MSIM3103 Business Analytics, the PI used the research results of configuration using default and best sellers as examples to show consumers' decision will be affected by the environment settings.

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.)

Building synergy among research units in the HSUHK: As the deep learning-based approach in our project requires extensive computing infrastructure support, the project fully leverages the facility of HSUHK's Deep Learning Research and Application Center (DLC). The center was set up in 2017 under the support of RGC project UGC/IDS14/16. We used the GPUs in DLC to implement our deep learning method. The RGC IDS project was acknowledged in our papers as well.

Training of research assistant: An RA was recruited under the support of this project. The RA performs data collection and annotation (together with an undergraduate student), and conducts experiments. Through the project experience, the RA learns the state-of-art machine learning and natural language processing techniques and is better prepared for his future career.

Undergraduate research opportunity: The project provides opportunities for undergraduate students to conduct research and develop their interests in research. This project leverages online product review data to build the needs-based configurator. Data quantity and quality play a critical

role in research development. An undergraduate student in the PI's Programme (Management Science and Information Management) helped crawl data from amazon.com and annotate the data. After the training of programming language such as Python, the student was well capable of the data crawling and annotation tasks. In addition, the student also attended the weekly project meeting to gain the experience of brainstorming research idea, presenting research result, etc.

13. Statistics on Research Outputs

	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	5 (two published in IEEE T-II, #1 in Industrial Engineering)	3	0	0	Type	No.
					NA	0

14. 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	