RGC Ref. No.:
UGC/FDS14/E07/17
(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**

Configuration-based recommendations for online product customization in e-commerce

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

| Research Team | Name / Post | Unit / Department / Institution |
|---|---|---|
| Principal Investigator | WANG, Yue / Associate Professor | Department of Supply Chain and Information Management / The Hang Seng University of Hong Kong |
| Co-Investigator | TSENG, Mitchell M* / Professor | International School of Technology and Management / Feng Chia University |
| Co-Investigator | MO, Yiu-wing / Associate 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 | 01/01/2018 | | |
| Project Completion Date | 31/12/2019 | 30/06/2020 | 18/07/2019 |
| Duration *(in month)* | 24 | 30 | 18/07/2019 |
| Deadline for Submission of Completion Report | 31/12/2020 | 30/06/2021 | 18/07/2019 |

## Part B: The Final Report

## 5. Project Objectives

5.1 Objectives as per original application

*1. to develop intelligent online product customisation methodologies and provide customised products in an efficient manner*

*2. to design an efficient configuration mechanism to elicit customer needs.*
*3. to develop the recommendation criteria based on the customer's specifications in the configuration stage*
*4. t develop new assessment methods to evaluate the proposed approaches*

5.2 Revised objectives

NA

Date of approval from the RGC: _____

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 intelligent online product customization methodologies and provide customized products in an efficient manner. It is also the overall objective of the whole project. To summarize, we made great efforts along this direction and have achieved interesting findings on intelligent online product customization methodologies. We developed a novel needs-based configuration-then-recommendation mechanism which takes customer needs in layman language as the input and transform the needs into tangible product configurations (Please check the two accepted journal papers in IEEE T-ASE and the IJPR submission which is under review). 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 design an efficient configuration mechanism to elicit customer needs. Objective 3 is to develop the recommendation based on the customer's inputs in the configuration stage. These two objectives are highly related and thus we would like to elaborate the realization of them together. One of the key issues of current online customization toolkits is that user experience is not fully considered in the design of the online customization interface. Traditionally, customers need to pin down the detailed product specifications using choice navigation toolkits, such as configurators. Due to the lack of domain knowledge, they may find the customization process confusing and hard to use. We proposed a needs-based configurators to tackle this issue. Customers just need to input their requirements to the online system using natural language. We then developed deep learning-based approaches to recommend the mostly likely accepted product configurations to the customers. Specifically, hierarchical attention model (HAN) and multitask learning are exploited to realize the recommendation (Please see the journal papers, J1 and J2). 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 the conference paper C2 and the journal paper J3 which is under review). Objectives 2 and 3 are fully achieved.

Objective 4 is to develop assessment methods to evaluate the proposed approaches. We mainly evaluated the proposed approaches using computational experiment and empirical study. The recommendation for configurable product 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 (such as watch and food) and utilitarian products (such as laptop, and bicycle). 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 can be found from conference paper C1, C3, and C4. 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 intelligent online product customisation methodologies and provide customised products in an efficient manner | ✓ | 100% |
| 2. to design an efficient configuration mechanism to elicit customer needs | ✓ | 100% |
| 3. to develop the recommendation criteria based on the customer's specifications in the configuration stage | ✓ | 100% |
| 4. to develop new assessment methods to evaluate the proposed approaches | ✓ | 100% |

## 6. Research Outcome

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

- Needs based product configurators to bridging semantic gap between customer needs and product configurations

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. We explore hierarchical attention (HAN) model to realize the needs-based configurator which can elicit customer needs in layman language and recommend the satisfactory products. It has been acknowledged that the customer needs extracted from product review are comparable from those extracted using traditional marketing research. Thus, we leverage product review texts crawled from e-commerce website to distil customer needs information. The attention mechanism in HAN could emphasize the informative keywords and thus make the neural network more efficient. Promising results were obtained (please see the journal paper in IEEE T-ASE, J1).

- Leveraging the dependency among product attribute choices during configuration-then-recommendation process using multitask learning

In addition, different attributes in a product a highly dependent. We proposed a multitask learning method to incorporate the dependency among attributes into the recommendation procedure. In multitask learning, multiple related configuration tasks are learned together based on shared representations of information in the data. This mechanism could facilitate each other's learning through the underlying shared representations and, thereby, enhance the generalization effect. We deployed ELMo to encode the contextual information of the words in the review and needs text. Experiments indicated that this could improve the effectiveness of the recommendation (IEEE T-ASE, J2).

- A lightweight configuration model for industrial application

Our investigation mentioned in the previous point (journal papers, J1 and J2) 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 (J3, under review at IJPR) 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.

- How the recommendation in different format affects customers decision making during the configuration process

An effective and efficient configurator should consider not only the effectiveness of recommendation, but also customers satisfaction and experience. We conducted experiment to study how the recommendations of attribute choices (in the format of default options and best seller options) affect consumers' decision making during online configuration process (Please see the paper C1, C3 and C4). Specifically, we investigate how the factors, such as product type, customers' degree of expertise, motivation to process information, mediate customers' configuration choices. We also investigated which factors are significantly affect customers' decisions, and whether customers satisfaction towards the customized product and the process improved with product recommendations provided. 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 this project as a promising start for the research directions of machine learning in design. Currently, a massive amount of product-relevant data can be extracted from e-commerce websites, including product reviews and product metadata. 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. Specifically, we deem the following two directions critical and would like to explore them in our future work. The first is to fully leverage the pre-trained language model to mine the unstructured text. The pre-trained language models, such as BERT, have revolutionized the research in natural language processing. It has a great potential to outperform existing methods. In this project, due to the resource availability, we did not explore much on pre-trained language model for the recommendation but would like to investigate it in the future. The second is to exploit knowledge graph and knowledge base for the recommendation. The methods proposed in this project are data drive and no prior knowledge is utilized. Equipped with external knowledge extracted from different resources, we are confident that the method could be more efficient. We plan to apply research funds from different funding agencies, such as RGC, to support our research along the mentioned directions.

## 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 has been prevailing for online product customization in e-commerce. 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 semantic gap between customer needs and the customized product family. This project developed a novel configuration-then-recommendation idea to bridge the semantic gap. A needs-based configurator is used to elicit customer needs expressed in natural language and transform the needs to the satisfactory product specifications. Deep learning-based approaches were developed to elicit the informative semantics from product review / needs text and realize the recommendation. Computational and empirical experiment results show great potential for the new breeds of configurators to be applied in industry. The proposed mechanism facilitates the online choice navigation process by shielding customers from the tedious process of screening and selection from many choices. We anticipate that the project could advance state-of-art engineering design and product customization research.

## 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)* | | | | | | |
| 2021 | | | | Yue Wang*, Wenlong Zhao, and Wayne Xinwei Wan | Needs-Based Product Configurator Design for Mass Customization Using Hierarchical Attention Network / *IEEE Transactions on Automation Science and Engineering*, 18(1), 195-204. | No | Yes (Annex I) | Yes | Yes |
| 2020 | | | | Yue Wang*, Xiang Li, and Fugee Tsung | Configuration-Based Smart Customization Service: A Multitask Learning Approach / *IEEE Transactions on Automation Science and Engineering*, 17(4), 2038-2047. | No | Yes (Annex II) | Yes | Yes |
| | | 2020 (revised and resubmitted in 2021) | | Yue Wang*, Xiang Li, Linda Zhang and Daniel Mo | 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 III) | RGC support will be acknowledged after the manuscript is accepted for publication | 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)* |
|---|---|---|---|---|---|---|
| 09/2018/ Graz, Austria | The Effect of Default Options on Consumer Decisions in the Product Configuration Process | The 20th International Workshop on Configuration | 2018 | Yes (Annex IV) | Yes | Yes |
| 12/2018/ Hong Kong | Mapping Customer Needs in Natural Language to Product Specifications by Using Word Embeddings | The Asia Pacific Industrial Engineering & Management Systems Conference 2018 | 2018 | Yes (Annex V) | Yes | Yes |
| 12/2018/ Bangkok | Observational Learning in the Product Configuration Process: An Empirical Study | IEEE Conference on Industrial Engineering and Engineering Management | 2018 | Yes (Annex VI) | Yes | Yes |
| 12/2019/ Macau | Observational Learning in the Product Configuration Process: The Effect of Information Presentation Format | IEEE Conference on Industrial Engineering and Engineering Management | | Yes (Annex VII) | Yes | Yes |

**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 deep learning-based approaches in our project require extensive computing resources 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 IDS project UGC/IDS14/16. We used the GPUs in DLC to implement our deep learning methods. Thus, the FDS project showcases a collaboration among research units in HSUHK and the synergy among different RGC funded projects.

**Collaboration with other institutes**: We seek the collaboration opportunities with other universities to conduct the research. such as The Hong Kong University of Science and Technology [redacted], IESEG in France [redacted] and Cambridge University [redacted]. The collaborators help capture raw data, pre-process the raw data and propose recommendation approach for configurable products.

**Training of a 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. The RA has been admitted to a PhD programme in The City University of Hong Kong after project.

**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 online customization methods. 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** | 2 accepted (IEEE T-ASE, the flagship journal in IEEE Robotics and Automation Society), 1 under review (IJPR) | 4 | 0 | 0 | Type | No. |
| | | | | | | |

## 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 |
|---|---|
| NA | |