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学位(専攻分野)	博士(情報学)
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(Form 3)

Summary of Doctoral Thesis

Name in full Sano, Shin

Title Human-AI Interactive Design Concept Exploration in Lexicosemantic Space

We have explored methods of supporting designers' creativity with computational processes. In the initial stage of styling design concept development and communication, the emotions, aesthetic sensations, and mental images that are evoked when the product is owned and used are expressed in highly abstract language and visual information, which are then discussed among the stakeholders to adjust and build consensus on the direction of the design concept.

These are critical tasks for designers, though word selection, combination, and composition of visual information are traditionally dependent on the designer's individual skills. Our grand hypothesis is that designers' cognitive activities in ideating novel design concepts can be enhanced by linguistic and visual stimuli with underlying lexicosemantic principles. This study combines recent developments in Natural Language Processing (NLP), Computer Vision, and Human-Computer Interactions.

We developed a series of web applications that assist users in composing a visual mood board to test this hypothesis and conducted participant experiments to verify its effectiveness. In addition to the combination and composition of visual information, there is another element of a mood board: the Design Concept Phrase (DCP), which is a combination of two adjectives. Concept designers explore and articulate the target product aesthetics and semantics in a DCP. A DCP conveys product semantics and aesthetics to stakeholders, and it is often used with contrasting terms that convey what is not their target design concepts. Designers often utilize this dichotomy technique to communicate the nature of their aesthetic and semantic design concepts, especially in an early design development phase. We aim to support this designer's cognitive activity with computational procedures.

To verify the effectiveness of a tool that incorporates these two elements, we decomposed them and developed the tools for each to verify the effectiveness of each through participant experiments. We first present the “Design Concept Exploration Graph” (“D-Graph”). It assists industrial designers in creating an original design-concept phrase (DCPs) using a ConceptNet knowledge graph and visualizing them in a 3D graph. The retrieval algorithm helps users find unique words by ruling out overused words based on word frequency from a large text corpus and words that are too similar between the two in a combination by the cosine similarity from ConceptNet Numberbatch word embeddings. Our study with the participants suggested the D-Graph has a potentially positive effect, though we needed to improve the UI to help users

adhere to the use of the algorithms in the intended ways.

To address the issues on the D-Graph, we propose the second system, the ``Character Space Construction'' (``CSC''). The CSC assists designers by constructing a ``Character Space'' (``CS''), which is a semantic quadrant system, in a structured manner. A CS created by designers with the assistance of the CSC enables them to discern and explain their design concepts in contrast with opposing terms. These terms in a CS are retrieved and combined in the CSC by using the ConceptNet knowledge graph. The CSC presents terms and phrases as lists of candidates to users from which users will choose in order to define the target design concept, which is then visualized in a CS. The participants in our experiment were given two conditions under which to create DCPs and explain them. The result showed that the group assisted by the CSC indicated their tasks were supported significantly better, especially in exploration, as measured by the Creativity Support Index (CSI).

Lastly. we propose the ``Mood Board Composer'' (``MBC''), which takes a DCP generated by either of the previous tools. It explores, finds, and arranges nine images in a $3¥times3$ grid system. Our proposed algorithms allow users to iterate the image search in an intuitive and effortless way. We develop the tools based on a hypothesis that the more iterations a user is engaged in, the more satisfying and creative the user feels about their experiences with the tool on the mood board creation task. We further explore the different versions of the iteration algorithms in ways of implicit interactions and feedback mechanisms users can be naturally involved in. The Non Word Calculation (NWC) aims for a simple and quick iteration by deleting undesired images and going on to the next search sessions. The Average Vector (AVV) utilizes the Vision API to acquire semantic labels on each image that are processed to explore the semantic vector space for query modification for the next search. The Label Feedback (FDB) allows users to observe and manipulate the semantic labels associated with the images and to provide feedback to the label in a way that will negatively affect on the system in obtaining the new query for the next search. We conducted a large-scale experiment with 420 cases of mood board creation, and the result supported the primary hypothesis of the iteration effect. The post-hock analysis on log data suggested insights about the optimal number of iterations and how the users explore and exploit the lexicosemantic space with the image operations.

Form8 : Separate Sheet
（様式８・別紙１）

Results of the doctoral thesis screening

博士論文審査結果

Name in Full
氏 名　Sano, Shin

Title
論文題目　Human-AI Interactive Design Concept Exploration in Lexicosemantic Space

本学位論文は,「Human-AI Interactive Design Concept Exploration in Lexicosemantic Space」と題し，全 7 章から構成されている.

第 1 章「Introduction」では，まず，研究の動機，背景，仮説について説明されている.次に，第 2 章「Related Work」では，創造性と言語，組み合わせ創造性，知識グラフ，創造性の評価基準等の関連研究について説明されている．ここで，本研究の目的が,「デザイン概念フレーズの生成とムードボード作成を探索的なインタラクションにより支援するアルゴリズム・AI システムの開発」であることが述べられている．ここで，ムードボードとは，商品開発のデザイン概念を説明するために用いられる，複数のイメージ画像を 2 次元に配置した画像コラージュである.

続いて，第 3 章「Design Concept Exploration Graph (D-Graph) 」においては，プロトタイプシステムである Design Concept Exploration Graph (D-Graph)の方法論，システム開発，そして参加者実験の計画・実施・結果の分析について説明されている．そして，第 4 章「Character Space Construction (CSC) 」では，デザイン概念フレーズ生成の手続き化，検索方法の改良，グラフィカルユーザインタフェース(GUI)の改良により D-Graph を拡張した Character Space Construction (CSC)システムについて，その方法，評価実験の説明がされている.

次に，第 5 章「Mood Board Composer (MBC) 」では，先のデザイン概念フレーズを入力とした画像の適合フィードバックによって，デザイン概念の説明のための画像コラージュであるムードボードを半自動生成できる Mood Board Composer (MBC)の方法，評価実験，実験結果の分析について述べられている．最後に，第 6 章「General Discussion」で，研究全体の考察がなされ，第 7 章「Conclusion」において論文全体がまとめられている.

公開発表会では博士論文の章立てに従って発表が行われ，その後に行われた論文審査会及び口述試験では，審査員からの質疑に対して適切に回答がなされた.

質疑応答後に審査委員会を開催し，審査委員で議論を行った．審査委員会では，出願者の博士研究が「計算論的創造の手続きをアルゴリズム化，システム化した新しい試み」であることが評価された.

以上を要するに本学位論文は，ムードボード作成を題材として，AI により計算論的創造を支援するシステムのアルゴリズム開発，システム実装および参加者実験による評価をリゴラスに行ったものであり，研究分野の発展に貢献しているという点で学術的価値が大きい．また，本学位論文の成果は，学術雑誌論文 1 件，査読付き国際会議論文 1 件として発表され，社会的な評価も得ている．以上の理由により，審査委員会は，本学位論文が学位

の授与に値すると判断した.