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理事長序

本期為今年發行之第十三卷第 2 期期刊，共收錄兩篇英文研究論文、兩篇中文研究論文與一篇中文創作報告。首先，英文論文部份：探討內容包括，第一篇為英文研究論文「影響社交網路服務用戶使用表情符號的因素：台灣、日本和韓國比較」，採用技術接受模型（TAM）和技術接受與使用統一理論（UTAUT），驗證影響表情符號在社交服務網路中使用的因素。從台灣、日本和韓國採集 422、153 和 158 個有效樣本，並通過 AMOS 21 和 PLS（偏最小二乘法）進行分析。結果發現，台灣樣本的感知有用性、感知易用性、主觀規範、感知趣味性和時尚參與度對使用意願有正向影響。對於日本樣本，只有感知有用性、主觀規範和感知趣味性對使用意願有正向影響；對於韓國樣本，只有主觀規範和感知趣味性對使用意願有積極影響。第二篇為英文研究論文「不同設計形式鳥類生態資訊的視覺化」，探討台灣的鳥類物種，並使用內容分析來探索生態資訊在中的呈現方式，包含二維目錄、資訊圖表和智能手機應用程序等設計形式。結果顯示 (1) 二維目錄呈現的資訊量最大，資訊複雜性最高，其次是智慧手機應用程序和資訊圖表。(2) 運用圖文並茂的方式，全面展現視覺元素； 圖形符號的使用有助於用戶搜索資訊，圖形渲染可用於增強鳥類的視覺特徵。(3) 設計者可以在 app 開發過程中引入足夠的功能和界面設計，以提高用戶瀏覽和記錄鳥類特徵時的便利性。第三篇為中文研究報告「飛機檢修行動學習之研究」，行動學習結合擴增實境、虛擬實境及混合實境的發展已漸普及於各個領域。飛機檢修行動學習之研究以 A330 空中巴士煞車器的安裝模擬訓練為例，透過 3D 動畫模擬、互動設計及影片輔助教學方式，建置具教學、訓練、考測三模式的行動學習平台，藉以讓學員理解飛機檢修的相關知識與步驟。結果顯示，透過混合實境動畫模擬，對於訊息傳達正確性及使用者興趣與記憶度上都有正面作用。研究相信運用混合實境的行動學習發展，對於注重工業安全的教育訓練而言，將能帶動企業培訓的另一波革新思維。第四篇為中文研究論文「學術資訊視覺化網路系統的建立與應用-以 WOCAD 學術資料庫為例」，以 WOCAD (Web of CAADRIA) 資料庫作為數據來源，該數據庫是來自 CAADRIA 會議 1996-2015 年的精煉關係數據。由於 CAADRIA 作為電腦輔助設計 (CAD) 中的一個特殊興趣小組 (SIG) 的性質並針對此單一領域做知識的累積及拓展，這些數據提供了不同於一般學術資訊的領域特定信息且非常適合表現在該領域中的意義。最後一篇為中文創作報告「原著英雄造形創作之研究-以孫悟空為例」，《西遊記》本研究的主題是《西遊記》一書的孫悟空，藉由文獻探討以比較孫悟空在近代動漫市場上的造形形象演變，分析不同時期的形象特色。本研究所創造的孫悟空，提供一個可供未來類似題材參考的設計樣板，運用於《西遊記》題材的相關商業創作時，可以結合在古裝的《西遊記》相關的電影或動畫、遊戲，也可融入現代的英雄舞台，貼近本世紀忙碌卻心靈空泛的觀眾心中。最後，本期來稿 16 篇，作者包含台、日、韓國籍，經內審通過 7 篇論文進入雙匿名審查，審查結果 5 篇論文接受刊登。感謝各方學術先進賜稿，提升了本刊研究內涵，以及協助審查的評閱委員們給予學術與實務專業協助，深化本刊學術與深度及創作專業。

理事長

范國光

Foreword by the Chair

This issue is the volume 13and number 2 of this journal, which contains a total of two original research papers in English, two original research papers and one creative report in Chinese papers. The papers are including **1**. “Factors Affecting the Use of Emoji by Social Network Service Users: A Comparison of Taiwan, Japan and Korea”, this study used the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT) to find out and verify the factors affecting the use of emoji in social service networks. The results showed that the perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement of the Taiwanese samples had a positive impact on usage intention. For the Japanese samples, only perceived usefulness, subjective norms and perceived playfulness had positive effects on usage intention; for the Korean samples, only subjective norms and perceived playfulness had a positive effect on usage intention. **2**. “Visualization of Birds’ Ecological Information in Different Design Forms”, this study focused on bird species in Taiwan and used content analysis to explore the presentation of ecological information across three design forms: two-dimensional catalogs, infographics, and smart phone apps. These results imply that (1) 2D catalogs present the greatest amount of information with the highest information complexity, followed by smart phone apps and infographics. (2) The use of pictorial illustration comprehensively displays the visual elements; the use of graphic symbology helps users search for information, and graphic rendering can be used to enhance the visual characteristic of birds. **3**. “Research on Mobile Learning for Aircraft Maintenance”, this research is to develop mobile learning research in aircraft maintenance. It takes the installation simulation training of maintenance of A330 Airbus brakes as an example, through 3D animation, interactive design and instructional videos. The research results show that through virtual reality animation simulation, it has a positive effect on the accuracy of information transformation and the user's interest and memory. **4**. “Developing an Academic Information Visualization Network System- using WOCAD academic database as an example”, this article investigates an academic visualization network system with information visualization process. The data sources that this article uses is the WOCAD (Web of CAADRIA) database that is a refined relation data from CAADRIA proceedings from 1996-2015. From this network, the author's academic development depth and expansibility can be explored to evaluate the author's presence in the academic circle of computer aided design (CAD). **5**. “A Study on the Creation of Heroes in the Original Works-Taking Monkey King as an Example”, this research focuses on the Monkey King from the book "Journey to the West ." The literature compares the evolution of Monkey King's design in the modern animation market and analyzes the lack of elements in different periods. When the superhero Monkey King uses the commercial creation of the theme of "Journey to the West" in the future, it combines with the "Journey to the West" related movies, animations, games or incorporating into modern stage plays. Totally, there were 16 manuscripts submitted to this issue of the journal, and 7 papers passed the internal review and entered the double anonymous review processes, 5 papers were accepted for publication eventually. Additionally, three nationalities of authors were involved in this issue, which are Taiwan, Japan and Korea. Thanks to the authors for their contributions. Thanks to the reviewers for their professional reviews.

Chairman **Kuo-Kuang Fang** 2021. 12. 31

Factors Affecting the Use of Emoji by Social Network Service Users: A Comparison of Taiwan, Japan and Korea

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ABSTRACT

With the development of Internet and mobile devices, social network services (SNS) have become an indispensable part of people's daily lives, and with the popularity of SNS, users have also changed their ways of communication. However, online text communication between people lacks nonverbal cues, which often leads to misunderstandings or ambiguity. Emoji, a common language in the digital age, is often used not only in communication between different social network systems, operating systems and languages, but also by the users of SNS as the first choice for non-speech communication. This study used the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT) to find out and verify the factors affecting the use of emoji in social service networks. In this study, 422, 153 and 158 valid samples were collected from Taiwan, Japan and Korea, respectively, and were analyzed by AMOS 21 and PLS (partial least squares). The results showed that the perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement of the Taiwanese samples had a positive impact on usage intention. For the Japanese samples, only perceived usefulness, subjective norms and perceived playfulness had positive effects on usage intention; for the Korean samples, only subjective norms and perceived playfulness had a positive effect on usage intention.

***Keywords*:** Emoji; SNS; Cross-cultural research

1. Introduction

In the digital communication era, people can easily express their creativity and feelings in different ways. The development of social network services (SNS) has driven such phenomena and given users novel ways to communicate with others. In practice, attention should be paid to the use of emoticons (e.g., kaomoji, emoji, stickers, etc.) when using SNS, because these symbols can help users depict and convey facial expressions and gestures when communicating online. Compared with face-to-face communication (F2F), online communication lacks nonverbal cues that can prevent misunderstandings (e.g., body language or facial expression communication, etc.), which can easily cause ambiguity or misunderstandings (Daft & Lengel, 1984; Sproull & Kiesler, 1986). However, we can also use images to assist users to clearly express their emotional state and complete context in communication. Through these cues, individuals can overcome the ambiguity of text messages and improve the quality of communication.

This study focused on the factors that affect users' intention to use emoji in SNS. Emoji is different from kaomoji/emoticons, as it conveys the mood by combining images with colors. Emoji is a popular language that originated in Japan. It is a combination of え, e and もじ, which is pronounced as moji in Japanese, and which can be understood as meaning "writing that looks like painting". It was first used to let other parties know more about meaning and emotion in the process of communication. Later, computers began to recognize it as a form of text, thus making it a new form of written communication.

SNS has become a global trend, and its use has mushroomed (Boyd & Ellison, 2007). The subjects discussed in this study were from Taiwan, Japan and Korea, all of which are countries with a high proportion of network development, mobile device ownership rates, and SNS usage, etc. (National Development Council, 2019; Ministry of Science and ICT, 2019; Ministry of Internal Affairs and Communications, 2020). It has also been pointed out that with network development, the high usage rate of mobile devices and community services will promote the use of

SNS and indirectly improve the use of nonverbal cues, such as emoji, kaomoji and stickers (Kato, 2018). Some studies have also shown that the use of emoji in SNS has become increasingly frequent (Kato, 2019) and has been evaluated as being attractive, positive, creative and meaningful (Kitamura & Sato, 2009; Kuribayashi, 2010). Therefore, the intention of using emoji in SNS should be discussed. However, there are few researches on users' intention to use emoji in SNS, and there are not many related researches on factors that affect users' intention to use emoji. Therefore, this study intended to fill the gaps in the literature by exploring the behavioral intention of using emoji in SNS.

This study adopted the technology acceptance model (TAM) proposed by Davis (1986) and the unified theory of acceptance and use of technology (UTAUT) developed by Venkatesh et al. (2003), which is based on the TAM. These two models are often used to explain and predict users' patterns in receiving information systems and to explore the behavioral intention of using emoji in SNS. In this study, three variables of TAM (perceived usefulness, PU; perceived ease of use, PEOU; and subjective norms, SN), one variable of UTAUT (behavioral intention, BI), perceived playfulness (PP), and fashion involvement (FI) were introduced to establish the whole research model. This study aimed to explore and compare whether the perceived usefulness, perceived ease of use, subjective norms, perceived playfulness, and fashion involvement of users in Taiwan, Japan, and Korea related to using emoji would affect their usage intention, and the results could be used as a reference for the future research on emoji services in SNS.

2. Literature review

2.1 TAM & UTAUT

TAM, proposed by Davis (1986), is based on the theory of reasoned action (TRA) put forward by Fishbein & Ajzen (1975) and the theory of planned behavior (TPB) developed by Ajzen (1991), which is derived from TRA. TAM applies the user's cognition to discuss the acceptance degree and the decisive factors between the user and the use of science and technology. The model indicates that perceived usefulness and perceived ease of use are two important factors affecting the user's intention. Subsequently, Venkatesh & Davis (2000) found that subjective norms have a more significant impact when they are mandatory, and that they affect users' intention to use new things and new systems. TAM has been regarded as a complete model for many years and has been used to investigate users' acceptance of new technologies, as well as social media, e-commerce, software applications, and other multi-oriented research (Lorenzo-Romero et al., 2014; Zhang et al., 2008).

The UTAUT adopted in this study is mainly derived from the TAM. Venkatesh et al. (2003) reviewed and reconstructed eight models used in previous studies and further developed the TAM. This extended model combines TRA, TAM, the motivational model (MM), TPB, the combined TAM and TPB model (C-TAM-TPB), the model of PC utilization (MPCU), innovation diffusion theory (IDT), and social cognitive theory (SCT). It can explain many behaviors related to the adoption and use of new technologies. The main factors of the UTAUT model include performance expectancy (e.g., perceived usefulness), export expectancy (e.g., perceived ease of use), social influence (e.g., subjective norms & perceived playfulness), and facilitating conditions. Therefore, this study used UTAUT as our research model.

Many scholars have pointed out that TAM can be used to analyze users' use behavior and intention to use nonverbal cues such as emoji, kaomoji, and stickers. For example, Wang (2013) used TAM to explore the influence of stickers of the online community on the acceptance of digital natives, and the results showed that the stickers of the online community have a positive and significant influence on the perceived usefulness, perceived ease of use and behavioral intention of digital natives. Chen & Chen (2020) discussed users' intention when using ugly stickers, and found that ugly stickers are mostly used by young and extroverted users who frequently use SNS and are influenced by subjective norms. Nysveen et al. (2005) explored the moderating role of gender in the intention to use SNS, and the results showed that subjective norms are the determinant for female users, while perceived usefulness is the determinant for male users. Therefore, this study regarded perceived usefulness, perceived ease of use and subjective norms as disguised forms that affect the use intention of emoji, and put forward the following hypotheses:

H1: The perceived usefulness of using emoji in social network services has a positive effect on usage intention.

H2: The perceived ease of use of using emoji in social network services has a positive effect on usage intention.

H3: The subjective norms of using emoji in social network services has a positive effect on usage intention.

2.2 Perceived playfulness

The concept of playfulness originates from the nonverbal clues of media richness theory. When users have high interest in information technology, they will form subjective attitudes, such as positive emotions and satisfaction, while users who initially lack interest may interact with information technology with positive attitudes and strong motives. Playfulness can also attract participants' attention, trigger their curiosity, and let them be happy with interpersonal interaction (Hung et al., 2016). Chiang et al. (2011), Wang & Chang (2012) and Hung et al. (2016) also pointed out that playfulness is considered one of the keys to the success of SNS on social networking sites. Hedonic traits can give participants personal entertainment and cause fun and joyful emotions. Through the interesting and interactive traits generated by the community, participants can feel positive when interacting with others through social networking sites. Yu et al. (2005) and Chang et al. (2009) indicated that perceived playfulness has a positive and significant impact on the usage intention of information technology. Morosan & Jeong (2008) also found that perceived playfulness is an important predictor of users' intention to visit websites. Therefore, this study regarded perceived playfulness as a disguised form that affects the usage intention of emoji, and put forward the following hypothesis:

H4: The perceived playfulness of using emoji in social network services has a positive effect on usage intention.

2.3 Fashion involvement

Fashion is a process of accepting symbols that provide individuals with the same identification as others, and these symbols often change (Reynold, 1968). Sproles (1979) defined fashion as a form of behavior that is temporarily adopted by some members of a social group, and which is considered appropriate by society at a certain time and situation. This study discussed the adoption of new popular technologies such as SNS and emoji, as well as the willingness of individuals to use emoji.

In the field of fashion, the degree of fashion involvement refers to the range in which consumers are interested in the types of fashion commodities. Fashion involvement can be used to predict consumers' behavior variables related to fashion commodities, such as the product involvement degree, purchasing behavior, and consumer characteristics (Browne & Kaldenberg, 1997). The higher a user's involvement in fashion, the higher the user's recognition of the importance of fashion, the easier it is to use fashion in decision-making evaluations, and the more the emotion in use is influenced by the degree of love. O'Cass (2000) found that the degree of fashion involvement is highly correlated with personal characteristics and product knowledge, and that product knowledge can further affect users' use decisions. Watchravesringkan et al. (2010) also found that individuals who use fashion products generally do so to enhance their self-esteem and change their appearance. Therefore, this study regarded fashion involvement as a disguised form that affects the usage intention of emoji, and proposed the following hypothesis:

H5: The fashion involvement of using emoji in social network services has a positive effect on usage intention.

2.4 Research model

Based on the aforementioned related literature, UTAUT has been proven to effectively explain the prediction and performance of the behavior intention of the use of new technology (Blaise et al., 2018). The TAM mainly leads to use intention via perceived usefulness, perceived ease of use and subjective norms (Lorenzo-Romero et al., 2014; Zhang et al., 2008). In the research on information systems, perceived playfulness is found to directly affect the acceptance and use of technology. In the context of general users, perceived playfulness has also been shown to be an important determinant of the acceptance and use of technology (Brown & Venkatesh, 2005). Fashion involvement is a commonly-used statement and motivation that encourages users to adopt popular and novel technological products (Browne & Kaldenberg, 1997). Therefore, this study proposed that the use of emoji in SNS by users would be affected by the variables related to the hypotheses and would promote use intention. As personal characteristics are extremely important for predicting the behavior of technology acceptance and use, this study used UTAUT to explore the relationship between individuals' behavior and the intention to use emoji to establish a structural equation (SEM). The research framework is shown in Figure 1. This article explored the hypotheses and causality among perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement, behavioral intention and other dimensions, and proposed a model of the influencing factors and use intention of users to adopt emoji in SNS.

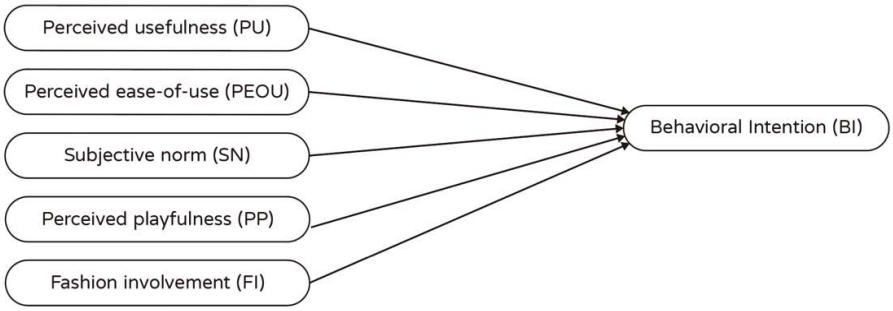

Figure 1. Concept model

3. Methods

3.1 Data collection

From January to February, 2021, this study conducted a network questionnaire survey on the use of emoji in Taiwan, Japan and Korea through SNS and network survey companies. A total of 422, 153 and 158 valid samples were respectively collected, and a total of 733 valid questionnaires were recovered. As shown in Table 1, there were 422 samples from Taiwan, with 54.8% male and 45.2% female, as well as 153 samples from Japan, with 49% male and 51% female, and 158 samples from Korea, with 45.6% male and 54.4% female.

This survey was based on the research ethics standards issued by the Japan Ergonomics Society and the International Ergonomics Association's Code of Conduct for Ergonomists, 2006, and was approved by the Bioethics Committee of Center for Frontier Medical Engineering, Design Research Institute and Graduate School of Engineering, Chiba University (R2-08). While the survey was in progress, the participants could close the browser to give up answering at any time, and their data would not be analyzed. All collected data was processed anonymously.

Table 1 Descriptive Statistics

Variable	Taiwan	Japan	Korea
	N / Percentage %	N / Percentage %	N / Percentage %
Gender			
Male	227 (54.8%)	75 (49%)	72 (45.6%)
Female	195 (45.2%)	78 (51%)	86 (54.4%)
Age			
20-29	196 (46.4%)	31 (20.3%)	57 (36.1%)
30-30	124 (29.4%)	49 (32%)	30 (19%)
40-49	66 (15.6%)	28 (18.3%)	46 (29.1%)
50-59	26 (6.2%)	29 (19%)	17 (10.8%)
60-69	10 (2.4%)	12 (7.8%)	7 (4.4%)
70-79	0	3 (2%)	1 (0.6%)
80-89	0	1 (0.7%)	0
Education			
Primary	2 (0.5%)	0	0
Secondary	49 (11.6%)	39 (25.5%)	29 (18.4%)
University < = 4	286 (67.8%)	101 (66%)	102 (64.6%)
University > 4	85 (20.1%)	13 (8.5%)	27 (17%)
Total	422	153	158

3.2 Measurement

The model constructed in this study adopted a verified scale. The original scales were all in English. We modified the scale to match the emoji, and translated the scale into Taiwanese Mandarin, Japanese, and Korean. The questionnaire mainly consisted of three parts. The first part was used for screening, in which we explained the purpose of the study and provided two questions for the participants to confirm whether they had used emoji and SNS. The respondents could not proceed to the next stage if they failed to confirm their usage, and if "have not used" was checked, the survey would automatically jump to the end screen. The second part of the questionnaire was demographic variables, including gender, age, and educational background. The third part was the scale of potential variables. The scale (Table 2) included the following constructs: perceived usefulness, perceived ease of use, subjective norms, perceived playfulness, and fashion involvement, which were developed from Moon & Kim (2001), Venkatesh et al., (2003), Lin & Bhattacherjee (2008), Tiger et al. (1976), Lin & Xia (2012) and Venkatesh & Davis (2000). A 7-point Likert scale was used for scoring, with answers ranging from 7 (strongly agree) to 1 (strongly disagree). There were two additional questions, including "How frequently do you read the fashion section in the media?" and "How frequently do you shop in department stores or consumer electronics stores?", for which the answers ranged from "Frequent" to "Very Few".

Before the questionnaire was officially issued, we conducted a pre-test and pilot test to verify the scale. For the pre-test, we invited eight experts to give their opinions and revise the format and wording of the questionnaire. Finally, we collected 75 questionnaires during the pilot test to reduce errors and deviations. In this study, Cronbach's alpha was used to confirm the reliability of all items (PU=0.94, PEOU=0.87, SN=0.85, PP=0.90, FI=0.76, BI=0.75), and according to Tu (2012) recommendation, the results indicated that the revised questionnaire items were credible and valid.

Table 2 Model Constructs and Items

Item	*Scale*
Perceived usefulness (PU) (Moon & Kim, 2001; Venkatesh et al., 2003)	
PU1	I like to use emoji.
PU2	I hold a positive attitude towards the use of emoji.
PU3	Using emoji brings me a lot of convenience.
PU4	The use of emoji can accurately express feelings other than words.
PU5	Using emoji helps to express my thoughts.
PU6	It is useful to use emoji.
Perceived ease of use (PEOU) (Venkatesh et al., 2003; Lin & Bhattacherjee, 2008)	
PEOU1	It was easy for me to learn how to use emoji when chatting at first.
PEOU2	The emoji I use at present are popular.
PEOU3	It is easy to chat with emoji.
PEOU4	It is a very simple thing to use emoji.
Subject norm (SN) (Venkatesh, & Davis, 2000)	
SN1	Colleagues/classmates in the workplace/school think I use emoji.
SN2	Peers outside the workplace/school think that I use emoji.
SN3	My family thinks I use emoji.
SN4	My friends think I use emoji.
Perceived playfulness (PP) (Moon & Kim, 2001; Venkatesh et al., 2003)	
PP1	Chatting with emoji makes me feel very interested.
PP2	Chatting with emoji will stimulate my imagination.
PP3	Chatting with emoji gives me a kind of intimacy to communicate with others.
PP4	Chatting with emoji makes me feel happy to talk with others.
PP5	Chatting with emoji makes me have a sense of presence face-to-face with people.

Fashion involvement (FI) (Tigert et al., 1976; Lin & Xia, 2012)	
FI1	I am a person who can keep up with fashion.
FI2	How frequently do you read the fashion section in the media?
FI3	How frequently do you shop in department stores or consumer electronics stores?
Behavioral intention (BI) (Venkatesh et al., 2003)	
BI1	I expect to continue to use emoji in the future.
BI2	I will use emoji as often as I do now.
BI3	I will recommend my relatives and friends around me to use emoji.

4. Results

This study used AMOS 21 statistical software to analyze the data from Taiwan, and used partial least squares (PLS) to analyze the data from Japan and Korea. As for Taiwan, in the first stage, first-order and second-order confirmatory factor analysis (CFA) was used to confirm the goodness-of-fit of models in the literature, as well as the reliability and validity of the observed variables and potential variables. In the second stage, structural equation modeling (SEM) was used to test the hypotheses. As for Japan and Korea, the model was analyzed through two steps: (1) reliability and validity to evaluate the quality of the model; and (2) structural model hypothesis testing.

4.1 Measurement model

In this study, the measurement model was evaluated according to criteria for the reliability, convergent validity, discriminant validity, construct validity and model-fit (Table 3). For these three models, the Cronbach's α of all items was higher than 0.7, indicating that the items of each variable had reliability (Fornell & Larcker, 1981).

Next, the factor loadings and the average variance extracted were used to test the convergence validity. The factor loadings of the project needed to be greater than 0.5, and the average variance extracted (AVE) had to exceed 0.5 (Hair et al., 2006). As shown in Table 3, the factor loadings of all models were higher than 0.6, and the AVE was also higher than 0.5. In addition, the AVE of Fornell & Larcker (1981) was also used to obtain the AVE value for each construct. When compared with the square of the correlation coefficient of the construct, the AVE should be greater than the square of the partial correlation coefficient to prove the existence of discrimination validity. The correlation coefficients of each construct of the three models in this study all conformed to the above principles. Therefore, there was discrimination validity between constructs, as shown in Tables 4–6.

In terms of the construct validity, the component reliability (CR) for perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement were respectively 0.93, 0.88, 0.92, 0.78, and 0.86 in Taiwan; 0.95, 0.93, 0.95, 0.94, 0.87, and 0.89 in Japan; and 0.97, 0.96, 0.96, 0.97, 0.94, and 0.93 in Korea. All coefficients were greater than 0.7 (Hair et al., 2006). In addition, in order to ensure that each scale could measure the degree of the constructed theory, confirmatory factor analysis was used to test the fitness of the measurement model.

According to the statistical analysis, the results of the confirmatory factor analysis for Taiwan's six constructs of perceived usefulness, perceived ease of use, subjective norms, perceived playfulness, fashion involvement, and usage intention showed the following indicators: χ^2 = 739.03; df = 260; χ^2/df = 2.84; RMSEA = 0.07; GFI = 0.84; AGFI = 0.87; and CFI = 0.94, all of which were higher than the standards previously considered acceptable by scholars (Bentler & Bonett, 1980; Schumacker & Lomax, 2004; Hu & Bentler, 1999; Doll et al., 1994; MacCallum & Hong, 1997) (χ^2/df < 5, RMSEA ≤ 0.08, GFI ≥ 0.80, AGFI ≥ 0.80, CFI ≥ 0.90), indicating that the measurement model could be appropriately adapted to the data of this study.

Table 3 Scale Measurement Properties

		Factor Loading			Cronbach's α			CR			AVE		
		T	J	K	T	J	K	T	J	K	T	J	K
PU	PU1	0.82	0.80	0.87	0.93	0.94	0.96	0.93	0.95	0.97	0.67	0.76	0.84
	PU2	0.78	0.76	0.91									
	PU3	0.86	0.93	0.95									
	PU4	0.80	0.90	0.92									
	PU5	0.81	0.93	0.92									
	PU6	0.85	0.91	0.93									
PEOU	PEOU1	0.72	0.73	0.91	0.88	0.89	0.95	0.88	0.93	0.96	0.65	0.76	0.86
	PEOU2	0.80	0.87	0.94									
	PEOU3	0.87	0.94	0.95									
	PEOU4	0.83	0.94	0.92									
SN	SN1	0.89	0.95	0.93	0.92	0.93	0.94	0.92	0.95	0.96	0.74	0.83	0.85
	SN2	0.87	0.92	0.93									
	SN3	0.79	0.88	0.91									
	SN4	0.89	0.92	0.91									
PP	PP1	0.83	0.83	0.92	0.90	0.93	0.96	0.90	0.94	0.97	0.65	0.77	0.85
	PP2	0.74	0.87	0.93									
	PP3	0.86	0.91	0.93									
	PP4	0.88	0.90	0.93									
	PP5	0.70	0.88	0.90									
FI	FI1	0.83	0.89	0.93	0.78	0.78	0.90	0.78	0.87	0.94	0.55	0.68	0.83
	FI2	0.75	0.85	0.92									
	FI3	0.63	0.74	0.89									
BI	BI1	0.90	0.93	0.95	0.83	0.82	0.89	0.86	0.89	0.93	0.67	0.74	0.82
	BI2	0.87	0.93	0.92									
	BI3	0.66	0.70	0.85									

Note: T=Taiwan; J=Japan; K=Korea; PU = perceived usefulness; PEOU = perceived ease of use; SN = subjective norm; PP=perceived playfulness; FI = fashion involvement; BI = behavioral intention.

Table 4 Correlation of Constructs – Taiwan

	PU	PEOU	SN	PP	FI	BI
PU	**0.85**					
PEOU	0.79	**0.86**				
SN	0.71	0.72	**0.90**			
PP	0.80	0.74	0.66	**0.85**		
FI	0.42	0.47	0.47	0.51	**0.84**	
BI	0.77	0.76	0.80	0.77	0.53	**0.87**

Table 5 Correlation of Constructs – Japan

	PU	PEOU	SN	PP	FI	BI
PU	**0.87**					
PEOU	0.72	**0.87**				
SN	0.68	0.69	**0.91**			
PP	0.70	0.60	0.59	**0.88**		
FI	0.26	0.31	0.29	0.30	**0.83**	
BI	0.76	0.62	0.72	0.67	0.31	**0.86**

Table 6 Correlation of Constructs – Korea

	PU	PEOU	SN	PP	FI	BI
PU	**0.92**					
PEOU	0.85	**0.93**				
SN	0.78	0.79	**0.92**			
PP	0.85	0.84	0.83	**0.92**		
FI	0.63	0.66	0.69	0.70	**0.91**	
BI	0.77	0.77	0.84	0.86	0.68	**0.91**

4.2 Structural model

This section describes the validation of the hypotheses of our study. Table 7 lists the results for all path coefficients, R^2 values, and significance levels. For Taiwan, the results of the research and analysis showed that perceived usefulness ($\beta = 0.157$, $p < .001$), perceived ease of use ($\beta = 0.14$, $p < .01$), perceived playfulness ($\beta = 0.235$, $p < .001$), fashion involvement ($\beta = 0.094$, $p < .05$), and subjective norms ($\beta = 0.388$, $p < .001$) all had positive effects on usage intention in H1, H2, H3, H4, and H5, which supported the research hypotheses. The R^2 value was 76.5%, indicating that the model explained a good degree of potential transformation. As for Japan, the R^2 value was 66.3%, which showed that the model explained the potential transformation degree well, but that only H1, H3, and H4 were supported, with perceived usefulness ($\beta = 0.406$, $p < 0.01$), perceived playfulness ($\beta = 0.179$, $p < 0.05$), and subjective norms ($\beta = 0.348$, $p < 0.01$). As for Korea, the R^2 value was 78.9%, which also showed that the model explained the potential transformation degree well. However, it only supported H3 and H4, with perceived playfulness ($\beta = 0.502$, $p < .001$) and subjective norms ($\beta = 0.364$, $p < .05$). These results once again confirmed the validity of the model and its applicability to the use of emoji.

Table 7 Structural Model Results

	Taiwan	***Japan***	***Korea***
PU	0.157**	0.406**	-0.019
PEOU	0.14**	-0.036	0.042
SN	0.388***	0.348**	0.364*
PP	0.235***	0.179*	0.502***
FI	0.094**	0.063	0.058
Participants (N)	422	153	158
R^2	76.5%	66.3%	78.9%

Significant levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5. Discussion and conclusion

This study mainly used the TAM and UTAUT to explore whether perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement affect use behavioral intention in Taiwan, Japan and Korea. The research hypothesis validation results indicated that the five concepts of perceived usefulness, perceived ease of use, subjective norms, perceived playfulness and fashion involvement had different influences on the intention to use emoji in social network services in Taiwan, Japan and Korea. The analyses and results illustrated the phenomenon of different countries, showed their practical significance and resulted in a number of suggestions for future non-verbal clues. We also used the differences in the three models of the research results to argue that cultural background should be adopted as the basis for using and adopting products of transnational technologies in the future. This result corresponded to the studies of Prada et al. (2018), Garrido & Prada (2021), Lu et al. (2016), Park et al. (2014), Takahashi et al. (2017) and Barbieri et al. (2016), who pointed out that different cultural geographies, backgrounds and environments will result in differences in the use of emoji. The contributions of the results of this study to the development of theory and practice were as follows:

H1: The analysis of the research results showed that perceived usefulness in Taiwan and Japan regarding the use of emoji in SNS has a direct and positive effect on the usage intention. H1 was therefore partially valid; however, Korea rejected H1. The results were partially consistent

with those of Venkatesh et al. (2003) and Wang (2013). The perceived usefulness of emoji directly affects the user's behavior intention. It could be seen that the usability of emoji is important to users. If users feel that emoji is functional and practical, it will increase users' willingness to use it. As for Japan, it was found that perceived usefulness has a greater influence on usage intention than perceived ease of use and subjective norms. This means that if Japanese people think emoji can improve the efficiency of their nonverbal cues in SNS, they will be more willing to use it. Kato (2015) pointed out that when Japanese individuals use SNS, they will use emoji to communicate with others in order to avoid embarrassing situations, which further promotes the use of SNS and reflects the usefulness of emoji. The failure of Korea was also inconsistent with the research results of Venkatesh et al. (2003) and Jung & Bae (2016). It shows that in Korea, users who use emoji do not interfere with the influence of perceived usefulness on usage intention.

H2: The analysis of the research results showed that Taiwan's perceived ease of use of emoji in SNS has a direct and positive effect on usage intention. H2 was therefore partially valid; however, Japan and Korea both rejected H2. The results were partially consistent with those of Venkatesh et al. (2003). As shown in current research on TAM, it is easy to understand that users regard emoji as something they could operate and use. Previous studies have also pointed out that perceived ease of use, and this study also pointed out that results will vary in different countries. The author considered that the people of Japan and Korea are relatively formal and restrained in terms of both language and life when compared to Taiwan. Accordingly, they must adopt different respectful sentences for language performance when facing different situations and objects, as the use of emoji is not necessarily an easy behavior. Similarly, they must also face the same problems when using emoji on SNS, as it is not easy to choose the appropriate emoji to use. From a practical aspect, emoji can be easily installed into the operating systems of today's computers, mobile phones and mobile devices, and many SNS developers also offer the function of automatically recommending emoji. Although emoji is a system invented in Japan, many emoji based on local cultures have also been developed in response to globalization. In the future, if operating system operators and SNS developers can create or strengthen their choice of non-verbal cues corresponding to various cultures, it will definitely increase emoji's ease of use.

H3: The analysis of the research results showed that the subjective norms of Taiwan, Japan and Korea when using emoji in SNS have a direct and positive influence on usage intention, therefore H3 held true. This result was consistent with that of Venkatesh et al. (2003). Subjective norms play an important role in the usage intention of emoji, and subjective norms (such as people's hope to establish or maintain a good image in the group) may enhance an individual's position in a group. It can be seen that other people's evaluation and opinion on emoji and the popularity of emoji will affect the user's intention to use emoji. In Taiwan, besides perceived usefulness and perceived ease of use, subjective norms are another important factor affecting users' usage intention. Nowadays, written communication between people is based on SNS. Users pay more and more attention to the connection relationship in the community. When using SNS, the recognition and degree of other people's views will affect users' usage intentions in the community.

H4: Taiwan, Japan and Korea have a higher degree of perceived playfulness in the presentation of usage intention when using emoji in SNS, and these results supported hypothesis 4. This result was consistent with the results of Venkatesh et al. (2003) and Moon & Kim (2001). Perceived playfulness is recognized by most subjects. Therefore, the pleasure of using emoji is an important factor affecting users, and the value of perceived playfulness is biggest motivation to promote the use of emoji. As for Korea, perceived playfulness is the most important factor affecting usage intention, which was consistent with Jeon's (2011) research results. Therefore, the popularity of emoji depends on how many users can perceive its playfulness. Internet utilization in Korea is quite high, and Internet cafes have become quite popular, thus providing an environment in which individuals can easily use SNS through network services anywhere. Therefore, it could be considered that emoji has perceived playfulness in Korea.

H5: The analysis of the research results showed that Taiwan's fashion involvement in using emoji in SNS has a direct and positive effect on usage intention. H5 was therefore partially valid, while Japan and Korea rejected H5. The results were partially consistent with those of Venkatesh et al. (2003) and Hou et al. (2010). Surprisingly, for users in Japan and Korea, fashion involvement has no effect on usage intention. The results showed that users in these two countries pay less attention to fashion involvement when using emoji in current SNS. On the contrary, in Taiwan, such findings could provide practical

implications for how SNS can attract users to use emoji by shaping fashion trends. This phenomenon could also correspond to the fact that many enterprises in Taiwan promote their products or corporate images through free software stickers.

Although this study strove to be rigorous, it still had a number of limitations. First of all, this study mainly focused on emoji, and it is necessary to carefully consider whether the research results can be generalized to other nonverbal clues in follow-up studies. Moreover, emoji may become outdated in the future; therefore, researchers should try their best to understand the influence of emoji, as well as communication using other nonverbal cues. More importantly, researchers should pay more attention to the characteristics of users, for example, this research focuses on the comparison of countries, and does not analyze the moderator variable of UTAUT such as gender, age, and experience. For example, this study explored the differences among people living in Taiwan, Japan and Korea; however, there will be other differences in countries or cultures outside Asia. Therefore, future research should explore whether the use of emoji in other regions will have different relationships, add different constructs, or conduct investigation from the perspective of social interaction, so as to discuss the changes and expansion of the research model and gain a wider and deeper understanding of the use of emoji.

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Visualization of Birds' Ecological Information in Different Design Forms

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ABSTRACT

This study focused on bird species in Taiwan and used content analysis to explore the presentation of ecological information across three design forms: two-dimensional catalogs, infographics, and smart phone apps. The reliability test conducted by two coders yielded a reliability score of 0.99, 0.97, and 0.98 for two-dimensional catalogs, infographics, and smart phone apps, respectively. These results imply that (1) 2D catalogs present the greatest amount of information with the highest information complexity, followed by smart phone apps and infographics. (2) The use of pictorial illustration comprehensively displays the visual elements; the use of graphic symbology helps users search for information, and graphic rendering can be used to enhance the visual characteristic of birds. (3) Designers can introduce adequate functions and interface designs during app development to improve user convenience when browsing and recording bird characteristics.

***Keywords*:** Information Visualization, Birds' Ecological Information, Visual Presentation, Design Form

1. Introduction

Information visualization is a scientific field combining information and visual design to convert various forms of information into graphic information that is easily comprehensible by users. Graphic information is displayed using interactive and visual approaches to help information receivers or users quickly understand the information content (Shneiderman, 1994). Designers face challenges highlighting the essential from an overwhelming amount of information to help users memorize key points. This challenge is the focus of information visualization. In recent years, the prevalence of tablets and smart phones has driven the development of digital content and changed conventional methods for presenting information. Information search methods have become increasingly intuitive and have changed users' approaches to understanding information. This facilitates information acquisition and improves user enjoyment when they browse information.

In recent years, the concept of environmental conservation has become increasingly prominent, and eco-tourism has also emerged. Tourists are encouraged to conduct sightseeing and travel on the premise of taking into account ecological conservation and development. Under the promotion of eco-tourism, the experience of the natural environment and the reception of related information are necessary conditions for people. Furthermore, an in-depth understanding of the ecology and biology of the region can help people improve their ability of ecological knowledge and appreciation. In the design field, the unique appearances, patterns, and colors of Taiwan's endemic species are often used as materials for cultural products, making them part of biological knowledge and aesthetic education in Taiwan. As a result, Taiwan's endemic species value research and education fields, also promote Taiwanese culture.

Among all species in Taiwan, birds are one of the most crucial indicators of environmental quality (Hsiao & Li, 2014). By observing birds, the importance of environmental protection can be better appreciated, and the relationship between natural–environmental changes and the lives, health, and safety of an area's residents can be better understood (Wang, Fang & Shih, 2015). The majority of bird learning materials in the past have been based on popular science books and illustrated handbooks, which feature natural photographs or realistic pictorial illustrations to introduce different bird species. Those books contain information about text introducing birds' features, characteristics, habits, etc. Furthermore, when using illustrations to present birds, it is essential to show their attributes for readers to distinguish the species. However, a variety of information is complex for readers to memorize in a short period when learning from books, resulting in people's generally lower awareness of Taiwan's endemic species.

When watching birds outdoors, the presentation of birds' ecological information requires fast and easy to use. By using visual images properly, readers can access and absorb information smoothly and memorize it with ease (Horton, 1994). The use of images can enhance the efficiency of communication, also help readers to absorb information nicely. This study used content analysis to explore differences among three design forms which are commonly used in presenting birds' ecological information — two-dimensional (2D) catalogs, infographics, and smart phone apps—in disseminating ecological information regarding birds in Taiwan. In addition, this study investigated methods for presenting visualized information. The results of this study can clarify the methods and presentation among different design forms when presenting ecological information. Furthermore, it can benefit designers to choose the proper design form to transmit information with target audiences, to accelerate ecological information dissemination, and help users quickly acquire ecological knowledge. This can enable users to understand Taiwan's ecological environment and elicit a sense of identity and empathy.

2. Literature Review

2.1 Visual Icons

Words, icons, and symbols are common elements of visual communication design. Designers can integrate words, icons, and symbols to provide information to users with the same language literacy background, thereby displaying diverse and comprehensive information. Among the aforesaid three elements, visual icons can be used to emphasize the key points of information, thereby attracting users' attention, improving concentration and memory, and guiding the learners' visual flows and viewing methods. In general, icons can better attract viewers' attention and help viewers memorize information than can simple words (Ashcraft, 1993; Messaris, 1997).

Hiebert (1998) noted that visual icons convert concrete objects into abstract ideas in which objects undergo simplification processes. In addition to abstraction, designers employ stylization. During this process, designers create simple designs through various techniques to emphasize specific details and convey graphic information and concepts. Stylized objects and graphics can leave stronger impressions on viewers and help them reflect on their own experiences by interpreting the meanings of objects or graphics. This also increases viewers' self-recognition (Grubb & Grathwohl, 1967; Kleine, Kleine, & Kernan, 1993; Atakan, Bagozzi, & Yoon, 2014a, 2014b). Given the extent of stylization, Meyer and Laveson (1981) divided graphics into five levels ranging from existing to abstract objects (Figure 1):

1. Natural photography, in which the visual cues of objects are fully presented using photography techniques.
2. Pictorial illustration, in which visual cues are fully presented and details are added to create a refined texture.
3. Graphic rendering, in which drawing techniques are used to retain the shapes and contours of objects, and colors and textures are simplified using blocks.
4. Graphic symbology, in which the shapes and contours of objects are simplified and the colors, textures, and sense of space are removed to flatten graphics and divide them into blocks.
5. Abstract symbology, in which the original shapes and contours of objects are destroyed, and geometrical shapes or free lines are used to display the designer's concepts

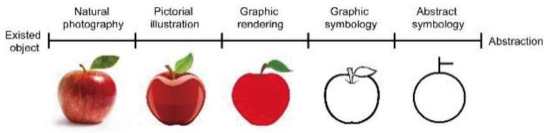


Figure 1: Stylization levels proposed by Meyer and Laveson (1981) (re-illustrated and used in this study)

2.2 2D Ecological Catalogs

A catalog is similar to an encyclopedia and serves as a reference book that provides clear information to help viewers identify objects. Because such books contain numerous pages and considerable amounts of information, readers may be scholars or people who are interested in such topics and only browse specific pages. The content of ecological catalogs includes textual descriptions, such as distinguishing features, habits, and the distribution of organisms and provides icons that help viewers identify the organisms. Therefore, icons in such catalogs must be drawn precisely for viewers to effectively identify species and names. This enables catalogs to be browsed quickly in outdoor environments.

This study focused on presenting birds' ecological information. 2D catalogs enable users to rapidly look up information while outdoors for confirmation of bird species. Accordingly, ecological catalogs must be easy to view and portable and provide essential information, including key features distinguishing similar species, clear geographic distributions, supplementary descriptions, and unique

characteristics and migratory behavior of species (Lin, 2015). Horton (1994) posited that effective use of visual icons helps viewers smartly use presented content and effectively presents visual and spatial concepts. Icons allow viewers to quickly distinguish essential information, increase their operating speeds, and enhance their memorization. In addition, icons do not require viewers to possess advanced reading ability; hence, icons help viewers acquire information immediately and accelerate information circulation.

Nowadays, relevant research on endemic species in Taiwan concentrates on conservation, animal and plant habits, and the ecological environment. Referring to Taiwan's endemic birds, most of the information is indexed in science and illustrated books. Moreover, the contents are arranged and sorted following the "The 2020 TWBF Checklist of the Birds of Taiwan (Ding, Juan, Lin, Tsai, Wu, Wu & Yang, 2020)" and "Clements Checklist of Birds of the World (Clements, Schulenberg, Iliff, Billerman, Fredericks, Sullivan & Wood, 2019)". However, for people who do not have enough background knowledge about birds, the well-arranged contents in the books are still having difficulties in leading readers to absorb knowledge and take them into practice. Current research on ecological publications focused on the existing book content, making further information verification or suggesting content updates, and less on the information layout or the context of using books. According to related research, applying the contents of 2D ecological catalogs to interactive picture books in augmented reality (AR) can effectively improve the learning effectiveness of elementary school children. And the pop-up catalogs can improve learning motivation (Lin, 2013). In short, when 2D catalogs combine with interactive technology to change the form of information presentation, it should effectively enhance the effectiveness of information absorption. Furthermore, rapidly developing biotechnology has accelerated changes in bird classification, which necessitates frequent updates of international illustrated checklists of the birds of the world.

2.3 Infographics

The application of infographics in Taiwan has become popular, and the content and topics have become diversified. As a result, the role and value of infographics on information transmission have gradually increased (Choi, 2018). During information visualization, infographics present information through visual design by using icons and words to display information. Theories and methods from different professional fields can be combined to summarize information, and design techniques can be used to convert abstract and complex information into simple icons, symbols, and textual descriptions. This conveys essential information to viewers, and information visualization is an outcome of interdisciplinary integration.

Zeleny (1987) proposed the Data Information Knowledge and Wisdom Hierarchy (DIKW) model, which categorizes information into four hierarchical levels: data, information, knowledge, and wisdom. Lai (2001) discussed the concept of information regarding information communication in which emphasis is placed on the essence, characteristics, and classification of information for upstream information dissemination. At the midstream, the organization, storage, and retrieval of information are emphasized. At the downstream, the transmission of information and relevant services is emphasized.

In addition to ensuring delivery of accurate information, infographics feature visual designs that present abstract concepts and complex data in an intuitive manner. This facilitates interpretation of information and makes the process interesting. That is, people feel pleasure when receiving information. Re-lab, a famous infographic design company in Taiwan, maintained that before deciding on the format of an infographic, information attributes must be understood to select the most adequate visualization method (Re-lab, 2017). Introducing the DIKW model and fundamental theories of information communication into infographic design enables identification of three essential elements of infographics: (1) raw data, (2) core concepts of information, and (3) presentation. The goal of infographic design is to clearly convey information and enable receivers or viewers to quickly understand complex or abstract information, thereby enhancing the memorability of information (Pettersson, 2010). In addition to the functionality of information communication, designers can use infographics to present abstract concepts and complex data more intuitively by making it legible and attractive. So that people can receive information smoothly with entertainment. Related research suggested no significant difference in the effectiveness of information learning between traditional teaching methods and teaching with infographics. However, infographics can significantly increase the participants' interest in information and learning motivation (Lin, Cai, Jian & Cai, 2020).

2.4 Information Visualization in The Digital Era

In recent years, the prevalence of tablets and smart phones have increased users' demand for mobile reading, driven the rapid growth of the digital content market, and demonstrated the potential of information visualization. Currently, information presentation is divided into three types: static, motion-type, and interactive (Pimenta & Poovaiah, 2010; Lankow, Ritchie, & Crooks, 2012).

Of the three types of presentation, static presentation is the most common and can be displayed on various media, including books, posters, computer screens, and smart phones. Users view static presentation to acquire information. However, limitations in human vision cause viewers to only acquire a limited amount of information within a specific period. Motion-type information incorporates visual and auditory effects and includes animations and music. These features attract viewers' attention; however, viewers cannot control their viewing speed. Consequently, the level of information acquisition may vary according to individuals' ability to absorb information. Interactive infographics can be modified flexibly according to the content and objectives of the information or viewers' characteristics. Viewers can use interactive functions to enhance their efficiency in acquiring information (Dur, 2014).

Studies have reported that when multi are used to improve individuals' learning and cognition by providing multiple stimuli simultaneously (e.g., visual, auditory, linguistic, and nonlinguistic stimuli) instead of a single stimulus, this enables individuals to learn efficiently and effectively memorize information (Mayer, 2001; Mayer, Lee, & Peebles, 2014). In short, adequate arrangements of interactive information can improve the efficiency of information acquisition and dissemination.

Based on preceding descriptions, interactive infographics were found capable of overcoming potential problems in static infographics (e.g., visual confusion) and avoiding the difficulty of information absorption due to users' inability to control the timeline of dynamic information. Interactive information enables users to decide when and how to view information and enables display of an appropriate amount of information in a single scene. Users may gradually absorb information through the process of autonomous exploration. Specifically, they can hide unwanted information as well as zoom in or out of certain sections of an infographic to input large amounts of information beyond the constraints of the screen space. Furthermore, through gestures or cursors, users can obtain the precise statistics or information from interactive infographics in a timely manner. This facilitates observations and cross-references by users without memorization, enabling users to effortlessly compare the relationships between heterogeneous data. Interactive information visualization has changed the information viewing habits of users; infographics not only convey information unilaterally, but also allow users to interact with information in a more intuitive manner.

In the digital age of data cloudification, electronic devices such as smartphones and tablets have become the most common carriers of information communication. Therefore, the style of visual communication design has been adjusted in response to the trend of the digital age. For example, the function of icons nowadays is more efficient than text description, which can instruct user's operation intuitively (Lin & Lai, 2015). Furthermore, the images or icons on the screen are primarily presented in a semi-representative to abstract way to show the information, reducing visual fatigue and taking into account the beauty.

2.5 Interactive Interface Design

In general, people are more capable of understanding information than memorizing information (Sharp, Pereece & Rogers, 2019). Therefore, interactive design should entail using graphics, text, and colors to help users integrate interface methods or information content with experiences or real-life memories. These generate favorable user experiences and help sustain long-term memories. Interactive interface design involves integrating graphics, text, and colors. These elements constitute the configuration of interactive methods and affect users' concentration and the ability to receive, learn, and memorize information when operating interfaces. Therefore, the focus of interactive design is to allow users to quickly become familiar with interactive interfaces, effectively acquire information, and have outstanding user experiences (Hoffman & Novak, 1996).

With the development and advancement of technology, the tourism model has changed from traditional leisure tourism to experience tourism with more learning and cognition (Bauer, 2012). World Tourism Organization (2011) proposed that experience tourism requires the third T to assist: travel, tourism, and technology. Moreover, the use of smart devices to guide travelers with educational purposes during travel has become the trend of tourism. With the prevalence of smart phones, interactive touch screens have become the main interface for cellphone users to receive messages (Lin & Lai, 2015). Adequate interactive interface design features, such as suitable function settings, browsing mechanisms, layout settings, and information combinations, enable users to flexibly operate interfaces and

acquire information and real-time feedback (Tidwell, Brewer & Valencia, 2020). When designing information interfaces for common, such as smart phones and tablets, designers implement special operating functions, including scrolling, clicking, and multitouch functions, to the interface to improve its usability. The sizes and locations of icons displayed on an interface affect users' accuracy and speed when operating the interface, which in turn affects user satisfaction (Park & Han, 2010).

Nowadays, the ecologically related apps on the market provide basic search and combine functions such as cameras and maps to help users inquire and record the types of animals and plants in real-time. In addition, some apps focus on ecological records in specific areas. For example, Chung Cheng University in Chiayi, Taiwan, has developed an app that explicitly records the campus ecological environment and combines it with web pages, Facebook pages, e-books, and publications to meet the adaptability of different operating systems and scenarios. This paper analyzed the different design forms of birds' ecological information in subsequent chapters to understand their characteristics, advantages, and disadvantages, as a reference for related research and design.

3. Types and Collection of Ecological Information

This study used content analysis to explore the presentation of ecological data in 2D catalogs, infographics, and smart phone apps to understand (1) the ecological information content of endemic bird species in Taiwan and (2) the presentation methods of information visualization. Content analysis involves examining the content of objects through unobtrusive methods and an objective and systematic attitude to determine the environmental context and conveyed meanings of the content (Lu, 2015). The data collection method is explained as follows.

3.1 The Data Collection of 2D Catalogs

2D catalogs are a conventional method of presenting ecological data. At present, most people still learn about birds through 2D learning materials such as popular science books and illustrated handbooks. After consulting biology and bird experts, this study used purposive sampling to select three bird catalogs and two representative bird catalogs in Taiwan: Birds of the World (Harrison & Greensmith, 1996), Wild Birds of Taiwan (Liao, 2012), A Field Guide to the Birds of Taiwan (Hsiao & Li, 2014), Fish Catalog: 700 Common Fish Species in Taiwan (Shao & Chen, 2003), and The Butterflies of Taiwan (Hsu, 2013). Three common types of content were compiled from these catalogs: (1) how to use these catalogs, (2) introductions to biological characteristics, and (3) biological information (Figure 2).

Figure 2: Example of presenting bird's features in 2D catalogs (Liao, 2012)

3.2 The Data Collection of Infographics

The infographic samples in this study were not limited to birds or endemic species. The five-kingdom classification model proposed by Whittaker (1969) was used to collect data (Campbell & Reece, 2004), and the DIKW model was used to analyze the infographic design process. Accordingly, the following three major elements of infographics were identified—(1) raw data, (2) core concepts of information, and (3) presentation—to select infographic samples. Finally, 29 infographics (7, 5, 5, 8, and 4 of which featured birds, fish, plants, mammals, and the environment, respectively) with content and visual integrity were selected for subsequent analysis (Figure 3).

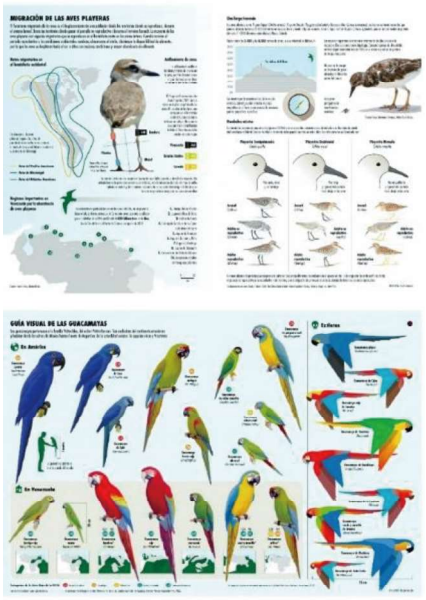


Figure 3: Example of infographics featured birds

3.3 The Data Collection of Smart Phone Apps

This study discovered that ecological information apps are mostly designed for smart phones instead of tablets, and most providers of such apps release the same version for smart phone and tablet users. Few apps are modified slightly to fit the size of device screens (e.g., iKnow Birds 2 LITE) (Figure 4). The six ecological information apps selected in this study were all compatible with the iOS system and have been updated within the last 5 years. These apps were Taiwan Birds (Eco-Education and Resources Centre Limited, 2016), Bird ID (Luo, 2016), Comprehensive Bird Catalog (Cao, 2015), EEbirds (Dept. of Electrical Engineering, National Taipei University of Technology, 2016), iKnow Birds 2 LITE (G.m.b.H., 2011), and iNaturalist (California Academy of Sciences & National Geographic Society, 2014) (Table 1). The function, strengths, weaknesses, and features of these apps were analyzed.

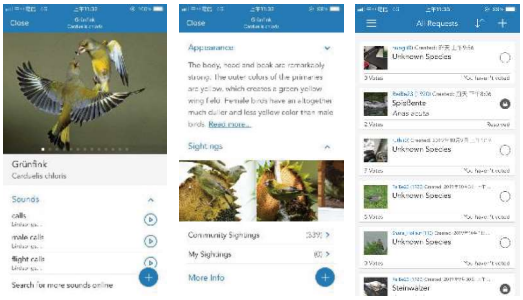


Figure 4: Example of presenting bird information in smart phone app (G.m.b.H., 2011)

Table 1: List of birds' ecological information apps discussed in this study

App name	Differences between smart phone and tablet versions of the app	Number of updates	Last updated
Taiwan Birds	No difference	-	-
Bird ID	No difference	9	June 27, 2019
Comprehensive Bird Catalog	No difference	1	October 16, 2015
EEBirds	Unavailable on tablets	2	March 30, 2016
iKnow Birds 2 Lite	Slight differences in interface design	11	March 5, 2019
iNaturalist	No difference	25	November 27, 2019

3.4 Data Encoding and Reliability Formula

Content analysis is a research method of systematic and objective inference (Dane, 1990). Any form of social artifact in communication, such as books, magazines, newspapers, paintings, can use content analysis (Babbie, 1995; Krippendorff, 2016). The execution method is for the researcher to analyze the content of the article systematically, and the purpose of the design of the category is to generate data suitable for the specific assumptions of the content (Kaplan, 1943). This research referred to the ten steps of the content analysis method proposed by Wimmer & Dominick (2000). It was divided into seven steps for this research, which were (1) determination of research purpose, (2) data collection, (3) construction category, (4) data coding, (5) reliability test, (6) data analysis and discussion, and (7) writing a research report. This study separately explored the differences in each design form's types, expressions, and appeals through the above methods.

Categorization is the core concept of content analysis, taxonomizing the content by using unique labels that group related pieces of content together. Categorization needs to be in keeping with three principles: mutually exclusive, exhaustive, and reliable (Wimmer & Dominick, 2000). This study constructed categories according to related research. The following were descriptions of each category.

1. Information presentation, including static, motion-type, and interactive. In addition, the form of information was defined according to chapter 2.4.

2. Visual elements, which were words, icons, and symbols. This study analyzed the visual elements used in different design forms, and the differences in the layout were also examined. In addition, icons and images were divided into five levels ranging from existing to abstract objects according to stylization.

3. The information content included introductions, user guides, names, photography or graphics, characteristics, habitat, habits, and sounds compared with information presentation and visual elements used.

Two coders with two-year interaction and graphic design background conducted data encoding according to the information content and framework of each medium. An expert has trained the coders with twelve-year interaction design and ten-year design research experiences. Before the training proceeded, the coders were taught the content analysis method to understand its operation and the basic knowledge about ecological information of Taiwan endemic birds. The training process included studying the encoder manual so that coders could fully understand the content and significance of the bird ecological information category and information architecture category. Furthermore, coders discussed the questionable category

according to the relevant references and modified the consensus into the encoder manual. Finally, a pre-test was proceeded before the formal encoding by using ecological illustrations, infographics, and mobile phone applications as pre-test samples to confirm that the analysis of the two coders is consistent.

The following are descriptions of information content and framework of each design form.

1. 2D catalogs

   Among the three kinds of design form, a 2D catalog comprised preface and detailed introduction to species. The preface had the following items: (1) user guide, (2) introduction, (3) glossary, and (4) preliminary introduction. Detailed introduction to species consisted of the following items: (1) name, (2) characteristics, (3) icon, (4) body length, (5) habitat distribution, (6) introduction of similar species, (7) living conditions, and (8) ecology. 2D catalogs of birds also cover their calls.

2. Infographics

   Infographics were divided into category, theme, and expression. Items of infographic category were (1) bird, (2) fish, (3) plant, (4) mammal, and (5) the environment. Items of infographic theme were (1) biological structure, (2) geographical distribution, (3) habit, (4) growth, (5) introduction of similar species, (6) conservation status, (7) life span comparison, and (8) incorporation of environmental conservation topics.

   Furthermore, Bird-themed infographics cover the following three additional items, namely bird call, feather color, and flight time. Expression of infographics comprised the following items: (1) map, (2) bar graph, (3) line graph, (4) pie chart, (5) flow chart, (6) route map, (7) relationship diagram, (8) rose plot, (9) bubble chart, (10) topographic map and others.

3. Smart phone apps

   Smart phone apps comprised functions and detailed introductions to species. Items of function were (1) keyword query, (2) search for characteristics, (3) record keeping, (4) sharing, (5) collection, (6) community, and (7) game. Furthermore, items of detailed introduction to species covered (1) name, (2) characteristics, (3) icon, (4) bird call, (5) habitat, (6) habits, (7) body length, and (8) conservation status.

After data encoding, the following reliability formula was used to analyze the scale's reliability.

Percent agreement = 2M/(N1+N2)

Reliability = (N*mean percent agreement)/

[1+(N-1)* mean percent agreement]

where M denotes the number of coding decisions upon which both coders agree; N1 represents the number of coding decisions made by the first coder; N2 is the number of coding decisions made by the second coder; and N denotes the total number of coders. The analysis results may serve as a reference for interactive information design.

4. Results

Content analysis was performed to explore and analyze the form and framework of existing ecological information presented in (1) 2D catalogs, (2) infographics, and (3) smart phone apps, thereby gaining understanding of the ecological information content of bird species indigenous to Taiwan and expression of information visualization. Two coders conducted content analysis of the three design forms discussed in this study. After data encoding, two coders performed reliability testing, of which the formulae and results are presented as follows:

1. The reliability testing result of 2D catalogs

   The number of coding decisions upon which both coders agree (M), the number of coding decisions made by the first coder (N1), the number of coding decisions made by the second coder (N2), and the total number of coders (N) were 54, 55, 55, and 2, respectively.

   Percent agreement = 2*54/(55+55)=0.98

   Reliability = (2*0.98)/[1+(2-1)*0.98]=0.99

   According to the analysis result, the information presentation type of 2D catalogs was static, which contained words and images, of which words were the primary and images were supplements. The images included natural photography and pictorial illustration, and icons composed of graphic rendering or graphic symbology. All 2D catalogs contained user guides and ecological information: name, characteristic, photography or graphic, length, habitat, and habit.

2. The reliability testing result of infographics

   The number of coding decisions upon which both coders agree (M), the number of coding decisions made by the first coder (N1), the number of coding decisions made by the second coder (N2), and the total number of coders (N) were 123, 127, 133, and 2, respectively.

Percent agreement = 2*123/(127+133)=0.95

Reliability = (2*0.95)/[1+(2-1)*0.95]=0.97

According to the analysis result, the information presentation type of infographics was static, which all contained words and images, of which images were the primary and words were supplements. The stylized levels of graphics in infographics were diverse, covering all five levels from natural photography to abstract symbology. The information mentioned includes name, appearance, biological structure, distribution, quantity, growth process, habits, sounds, similar species, conservation status, growth sequence, feather color, lifespan comparison, environmental conservation issues, flying time. However, none of the infographics contained all of the above information. Instead, one single infographic usually summarized above 1-2 kinds of information.

3. The reliability testing result of smart phone apps

The number of coding decisions upon which both coders agree (M), the number of coding decisions made by the first coder (N1), the number of coding decisions made by the second coder (N2), and the total number of coders (N) were 52, 54, 55, and 2, respectively.

Percent agreement = 2*52/(54+55)=0.95

Reliability = (2*0.95)/[1+(2-1)*0.95]=0.98

According to the analysis result, the information presentation type of smart phone apps was interactive, which contained words and images, of which words were the primary and images were supplements. The images included natural photography and fewer pictorial illustration, and icons composed of graphic rendering or graphic symbology. The information mentioned includes name, appearance, characteristics, length, habitat, habits, sounds, similar species, living conditions, and ecology. In general, the visual elements and information contents of smart phone apps were similar to 2D catalogs. All apps contained bird's name and photography. However, the information content and functions contained in each app were inconsistent.

The reliability score of the three design forms (i.e., 2D catalogs, infographics, and smart phone apps) were 0.99, 0.97, and 0.98, respectively; all were >0.9 and thus higher than the reliability threshold value (0.8). This revealed consistency between two coders' opinions regarding the sample and classification content. Further discussion of each medium is as follows.

4.1 The Analysis Result of 2D Catalogs

Overall, the sample catalogs present information similarly. According to the page order, the information is divided into three sections: (1) how to use the catalog; (2) preface, foreword, or preliminary introduction; and (3) detailed species introduction. Detailed species introduction includes information on the name, characteristics, images, and other details of the species. Name information includes common names, Chinese and English names, and scientific names. Characteristic information is presented using textual descriptions on the appearance and habits of species, including similarities and differences between males and females and sibling species. Images are primarily natural photographs or pictorial illustrations that showcase the physical appearances of organisms. In addition, size scales are used to illustrate the sizes and ratios of species.

2D images are also used to describe specific body parts of organisms. Detailed information includes the distribution, habitats, and habits of species, and is mostly presented at the edges of pages. As mentioned in Section 2, icons are more likely to attract viewers' attention than text and are helpful to viewers in distinguishing species. Therefore, icons are used in catalogs to replace text, hand-drawn illustrations, and habitat illustrations. This improves the usability of catalogs and viewers' ability to distinguish species. Table 2 compiles information presented using icons.

Table 2: Examples of icons for presenting information in 2D catalogs (Harrison & Greensmith, 1996; Liao, 2012)

Information	Icon	Meaning of the icon
Bird appearances and sizes		Left: size ratio between catalog and bird Right: body length and appearance
Bird appearances		Differences between male and female adult birds
Habitats		Habitat of a bird species

Regarding natural photographs and pictorial illustrations, the latter can freely showcase the appearances, standing stances, and flying motions of species and accentuate essential distinguishing features. These features are difficult to achieve using natural photographs

(Figure 5). Furthermore, birds of the same species may be difficult to distinguish across photos because of differences between individual birds. In addition, several catalogs in this study have considerable amounts of textual descriptions and disordered arrangements of text and images. This may cause viewers' difficulty in reading the catalogs or quickly browsing for required information.

Figure 5: Examples of pictorial illustrations highlighting specific body parts of bird species (Harrison & Greensmith, 1996)

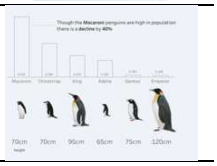
4.2 The Analysis Result of Infographics

The themes in infographics can be divided into the following types: (1) biological characteristics, (2) biological structure, (3) geographic distribution, (4) species population, (5) growth, (6) habits, (7) introduction of similar species, and (8) incorporation of ecological environment topics. Biological characteristics include information on species colors, physical appearances, and size ratios. Infographics with comprehensive information include at least two types of themes.

Examining infographic samples for the extent of stylization revealed that the visual information in infographics is presented using various methods, including natural photography, pictorial illustrations, and 2D shape drawings. Information in natural photographs is presented similarly to descriptions in catalogs, in which textual narratives are primarily used. In addition, shapes and symbols are used in paragraphs describing the main themes. This helps viewers quickly search for information. Pictorial illustrations are more suitable for comparing the sizes of bird species, describing details of specific body parts, and illustrating various movements and stances of birds. Graphic rendering is composed of simple colors and shapes and focus on highlighting the visual characteristics of birds, such as their overall physical appearances, color tones, and body ratios. Because colors and physical appearances are essential features distinguishing bird species, few infographics use graphic symbology or abstract symbology to present species information. Nevertheless, graphic symbology and abstract symbology occasionally appear in infographics as visual cues but they do not provide descriptive information of bird species or help viewers distinguish them.

According to differences in organisms' habits, the themes of infographics detailing these organisms vary. For example, the infographics collected in this study focused on bird species; hence, additional items of bird-themed infographics were (1) bird call, (2) flight time, (3) feather color, or infographic content on bird behavior mostly presented information such as birds' flying motions and migratory behavior. The theme of infographics also affects their presentation. For example, an infographic on biological structure may employ a breakdown drawing to enable viewers to gain information on the physical appearance and internal structure of organisms. Information on species distribution and habits are frequently present in graphics with maps, and lines or color blocks are used to indicate migratory routes and activity areas. By contrast, information on species population is typically presented using bar graphs or line charts to compare numbers of organisms across periods or between populations of species. Table 3 presents examples of infographics and how they are presented.

Table 3: Examples of infographics and how their themes are presented (Vieland, 2015; Ramallo, 2014; Umasankar, 2019)

Theme	Common presentation methods	Example
Biological structure	Breakdown drawing	
Distribution and habits	Maps with lines or color blocks	
Population	Bar graphs or line charts	

4.3 The Analysis Result of Smart Phone Apps

Bird ecological information provided in the smart phone apps includes details such as species names, types, physical appearances, and vocalization. In terms of functions and settings, EEbirds, Taiwan Birds, iNaturalist, and iKnow Birds 2 LITE have recording functions that allow

users to record bird species they encounter. In particular, iNaturalist has an in-app photography function that records the location and time of photos taken, and an image recognition function helps users distinguish bird species in photos.

Close examination of the information content in each app revealed that the species information provided in these apps was similar to those in the sample catalogs. The only difference was that the apps have additional functions for user interaction, such as keyword searching and birdwatching recordkeeping. Moreover, the apps feature multimedia recording and play functions. When recording bird species, users can use photography and location functions. This can increase users' convenience when recording information. iNaturalist and Bird ID employ image recognition technology to identify bird species. When users use iKnow Birds LITE to identify bird species on their own, the app asks whether they are confident with their identification. The users may share their identification results through the app as references for other users identifying bird species.

Using the six apps revealed that their usability is enhanced through user interaction and social functions. For example, the multimedia player functions of the apps can be used to play bird vocalization, which provides users with an alternative approach for visually identifying bird species. In addition, users can use the search functions, classification tags, and page switching functions to adequately display an overwhelming amount of bird species information. However, function icons in several apps are insufficiently intuitive or are placed in locations that are unexpected for users. This causes inconvenience when attempting to locate functions. These problems can be clarified in subsequent research through usability testing and user satisfaction surveys.

5. Discussion

According to the analysis results, this study compared differences between design forms in six areas: information quantity, information type, information complexity, usability, visualization level, and update speed. The results revealed that 2D catalogs present the greatest amount of information (including species, reproduction, color, population, habitats) and include primarily academic information that is diverse and complex. Therefore, looking up information in 2D catalogs is relatively time consuming. The requirement of checking the table of contents complicates the task. The limited know-how of learning users also reduces the ease of use of 2D catalogs.

The amount of information presented in a single infographic is limited by available space. Therefore, infographic can only present small amounts of information, and such information is typically condensed. The types of information presented in infographics also vary. Nevertheless, infographics convert complex information to easily comprehensible graphic information. Moreover, infographics can significantly increase readers' interest in information and learning motivation, which is more conducive to focused learning. The usability of infographics depends on how they are published. If infographics are published in books, users are likely to experience difficulty locating them. By contrast, infographics published online are easier to locate with proper keywords.

Rapid growth of the digital content market, expression of infographics, amount of content information, figure size settings, and incorporation of interactive functions may affect the ease of operation of infographics. The amount of information provided by smart phone apps is between 2D catalogs and the infographics. Moreover, smart phone apps offer various types of interactive functions. Users are provided with a menu that enables them to switch between pages, click on items according to their own needs, and obtain the information they are looking for. Convenient and easy-to-use smart phone apps facilitate interpretation and absorption of information. It has become the trend to use smartphones to assist with in-depth tourism so that the tourists can be guided and absorb information at any time. However, we hope to discuss an additional topic when establishing relevant information frameworks for a follow-up study, which is whether the functions, navigation mechanism, and information combination of a mobile app are relevant and allow users to obtain the feedback they need in real time.

Regarding the visualization level, 2D catalogs exhibit a low level of visualization and are mostly composed of simple text and image layouts. 2D catalogs mostly feature images of natural photographs and pictorial illustrations, both of which fully demonstrate the morphological characteristics of organisms. In infographics, design methods are used to convert abstract and complex information into graphic symbols and simple textual descriptions. Therefore, such design exhibit a high level of visualization. Extent of stylization of graphics is adjusted according to the theme of an infographic, mostly through natural photographs, pictorial illustrations, and 2D graphic depiction.

Information in smart phone apps is sorted using function settings and interface designs to ensure

readability. Images in such apps are mainly natural photos; hence, such design exhibit a moderate level of visualization. Because abstract symbology completely destroys the contours of organisms, it is only suitable for conceptual presentations and seldom used for presenting ecological information. The interface of most mobile apps nowadays often features flat and simplified icons to fit the relatively small screens and reduce the visual burden on users. Therefore, in the subsequent development of our bird ecological app, we will appropriately simplify bird images to adapt to the compactness of mobile phone screens, thereby meeting users' expectations of operating the app.

Update speed is another factor affecting the usability of design. The rapid development of biotechnology has accelerated updates on bird species classification; hence, bird catalogs must be updated frequently. Because 2D catalogs require a long publication process, the update speed of such design cannot keep up with the latest information on bird species. The production time of single infographics is shorter than that of books; however, time is still needed to collect and compile information. Therefore, compared with the other two design forms, infographics have a moderate update frequency. Smart phone apps have the fastest update speed because information can be updated online immediately. However, the results of this study revealed that several apps have a low update frequency. Therefore, when downloading the newest version of an app, users must pay attention to the most recent date the app was updated.

Nowadays, the majority of bird learning materials is based on 2D catalogs. The literature review in this research shows that applying the contents of 2D catalogs to interactive picture books in the form of AR can effectively improve the effectiveness of learning information. However, this method focuses on the presentation of AR images and the interaction between users, smartphones, and books, which cannot solve the problem of slow publishing and updating of the publications. Therefore, to transmit information efficiently, the website or app with the appropriate amount of information and the presentation should be taken to increase the efficiency of users' absorption of information through interaction. On the other hand, infographics with online publishing can help readers query and absorb information quickly when displaying specific information about birds. Table 4 comprehensively compares 2D catalogs, infographics, and smart phone apps.

Table 4: Comprehensive comparison of 2D catalogs, infographics, and smart phone apps (organized by the current researchers)

	2D catalogs	Infographics	Smart phone apps
Information quantity	Large	Small	Moderate
Information type	Diverse	Single/diverse	Diverse
Information complexity	High	Low	Moderate
Usability	Low	Varied	High
Visualization level	Low	High	Moderate
Update speed	Slow	Moderate	Fast

6. Conclusion

This study focused on bird species in Taiwan and collected ecological information from three types of design forms: 2D catalogs, infographics, and smart phone apps. Content analysis was performed to examine their information content, information compilation methods, and visual design styles. From the study results, the following conclusions were drawn:

1. 2D catalogs present the greatest amount of information with highest information complexity, followed by smart phone app and infographics. Although infographics carry the most diverse types of information and its presentation, the information is limited by the size of the paper or screen. As a result, infographics present a small amount of information with precise subjects.

2. Infographics reach the highest level of visualization, followed by smart phone apps and 2D catalogs. Based on the extent of stylization of graphics, ecological information content visualization has three main levels: (a) Pictorial illustration: this level comprehensively displays the visual elements, including the morphological characteristics, standing posture, and flying posture of birds. By choosing to omit or highlight certain image details, pictorial illustration accentuates the key features for recognition. (b) Graphic rendering: this level of design retains the detailed contours of birds, but simplifies the color palette and textures into blocks. This level highlights the visual characteristics of birds, such as their overall shape, tone, and body proportion. (c) graphic symbology: this level simplifies the shapes and contours of birds to flatten graphics and divide them into blocks, and is thus suitable for describing the main theme and retrieving information.

3. The visual elements and information contents of smart phone apps are similar to 2D catalogs, which shows less visualization and interaction than other app categories on the market. Designers can exploit the interactivity and sociability of smart phone apps to design relevant functions and interfaces (e.g., camera function, image recognition, and information retrieval with keywords) to improve the ease of use of apps in retrieving information and record keeping of birds.

The results of this study can be used to create information frameworks for the design and education fields and be a reference for subsequent studies by the current researchers to develop an ecological app for bird species in Taiwan. Heuristic evaluation, usability testing, and user satisfaction surveys will be used to explore how icons can be designed to clarify app functions and how they can be placed to meet users' expectations. The designed app should present abstract concepts and complex data intuitively and ensure that information is readable and interesting to allow users to enjoy using the app to acquire information.

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飛機檢修行動學習之研究

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摘要

近年來行動學習結合擴增實境、虛擬實境及混合實境的發展已漸普及於各個領域。飛機檢修行動學習之研究以 A330 空中巴士煞車器的安裝模擬訓練為例，透過 3D 動畫模擬、互動設計及影片輔助教學方式，建置具教學、訓練、考測三模式的行動學習平台，藉以讓學員理解飛機檢修的相關知識與步驟。本研究旨在探討適性化學習中，同化與固化發展策略使用在行動裝置，並透過混合實境互動安排，對使用者在認知與記憶學習的關聯性影響。其相關到 3D 動畫與互動介面安排等媒體呈現，最終反映在使用者滿意度與興趣表現上。研究以實驗法結合半結構式訪談，調查 33 位受測者及 5 位開發者的看法。研究結果顯示，透過混合實境動畫模擬，對於訊息傳達正確性及使用者興趣與記憶度上都有正面作用。研究相信運用混合實境的行動學習發展，對於注重工業安全的教育訓練而言，將能帶動企業培訓的另一波革新思維。

關鍵詞：行動學習、混合實境、適性化學習。

Research on Mobile Learning for Aircraft Maintenance

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ABSTRACT

In recent years, the development of mobile learning combined with augmented reality, virtual reality and mixed reality has been widely used in undertakings such as technical maintenance and other collaborative fields. The purpose of this research is to develop mobile learning research in aircraft maintenance. We take the installation simulation training of maintenance of A330 Airbus brakes as an example, through 3D animation, interactive design and instructional videos. The training system includes three selected items: teaching, training and testing, so that students can understand the relevant knowledge and procedures of aircraft maintenance. This research aims to explore the abilities of assimilation and solidification of adaptive learning strategies. These are related to media presentations such as 3D animation and interactive interface arrangements. The system's chief challenge is how to increase the system's attractiveness and memory points for students through the simulation and interaction of virtual situations. This research uses an experimental method combined with semi-structured interviews to investigate the opinions of 33 test subjects and 5 developers. The research results show that through virtual reality animation simulation, it has a positive effect on the accuracy of information transformation and the user's interest and memory. Therefore, we believe that the use of mixed reality action learning development will drive another wave of innovative thinking in corporate fields for education and training that focuses on industrial safety.

***Keywords*:** Mobile Learning, Mixed Reality, Adaptive Learning.

1 緒論

1.1 研究背景與動機

航空運輸安全與飛機維修有著密不可分的關係，其中相關到人為操作的因素。因此飛機檢修需具備更嚴格的準則並能在高壓條件下提升工作效能及減少人為操作的錯誤。飛機檢修行動學習之研究旨在透過行動學習輔具，達到增強工作效能與減少人為操作的疏失的目標，並著墨於工業教育訓練發展。飛機檢修行動學習不僅提供混合實境互動的情境模擬，更提供嚴謹與正確的資訊傳播與條件。

Wagner（2008）指出行動學習提供了一個遠距的學習環境及可能性，學習環境的變革是行動學習影響的重要項目。以上種種跡象顯示透過科技教育帶動下，行動學習發展進程從原本以教師講授為主體的訊息傳遞方式，漸朝向以學習者為主體的自主學習模式。雖然行動學習帶來正面效益持續發酵，但不可否認，參差不齊的行動學習內容與品質，也影響人們對數位教具的信心，而其大部分原因來自教學方法移轉不足及媒體特徵的無法善用有關。隨著自主學習風潮的興起，在缺乏正確科技素養與態度的同時，讓許多的網路社群等負面學習效應陸續呈現，其中包含如網路霸凌、假消息散布、資訊垃圾與資訊過載等現象產生。而這些在教育學習所帶來的隱憂，更不容忽視。

另一方面，身為多媒體開發者，我們經常懷疑多媒體是否真如萬靈丹一樣，具有學習的絕對優勢。Clark（1994）提出媒體無用論，來自他認為媒體只是傳遞者角色，就像輪胎對汽車的用途，不影響學習的成就。但身為媒體設計的工作者而言，對於多媒體呈現有效性質疑，是值得深思及改善的課題。因此找出媒體與學習的關係，也就是媒體互動的影響在認知與社會化過程，進而了解媒體特徵的相容與互補上差異，才能對知識進行更有效的傳達。本研究希望藉由行動學習教具的開發，來理解媒體特性對學習上的影響。

1.2 研究目的

飛機檢修行動學習教學策略以工業教導訓練（TWI-JI）所應具備的適性化原則下，透過成人教育（Andragogy）更具主動學習與有效學習來替代完全的自主學習（Heutagogy），藉以符合企業訓練更嚴謹規範。同時也希望藉由科技導師的輔助，為台灣企業降低人才培育成本。研究內容以開發行動學習（M-learning）教學系統，並以檢修 A330 空中巴士煞車器的安裝模擬訓練為例，設計具實用性且符合工業實作環境的行動學習平台。該教學策略強化在結構化、問題解決、最好的學習方式。內容針對適性化學習如何有效運用在行動裝置的互動設計上。本研究主分為二個面向發展：(1) 行動學習策略發展在成人教育上的同化與固化成效分析，(2) 媒材特徵的比較分析。(1) 成效分析透過認知(對學科的學習態度)、情意(對學科的自我感受)、技能(對學科的投入與練習)的學習量表，調查在此行動教具的學習動機與興趣滿意度上，藉以理解行動學習輔具在同化與固化的表現；(2) 媒材特徵則比較互動設計結合 3D 動畫模擬與傳統影片學習的差異，另外進行於媒體展示在圖文冗餘的研究。由於 3D 動畫媒材結合混合實境並可由任意角度觀察，能夠更接近遊戲的虛擬情境表現，對於強化特定訊息、簡化冗餘及提升學習興趣度上與傳統影片皆有所區隔。研究希望藉此實驗理解在不同媒材特徵的設計差異。

2 文獻探討

2.1 行動學習轉化研究

行動學習研究發展從紐西蘭的兩位學者 Cochrane & Rhodes（2009～2011）為期三年，針對行動學習藉由網路社群媒體的帶動所進行傳統教學的轉化。其目的在了解行動學習如何促進傳統教學環境轉化為學生自主學習環境所扮演的催化角色。期間行動學習除扮演訊息傳播的科技導師外，還必須將正規式學習環境與情境化（Situated）、真實性（Authentic）的非正式學習環境連接在一起。而 Cochrane（2013）還提出研究報告，並歸納出六項的行動學習成功因素。以下是行動學習六項成功要素說明：

(1) 教學將科技整合納入課程和評量中。

(2) 講師運用科技工具來構思及使用在教學法設計上。

(3) 創建一個支援性的學習社群。

(4) 適當的選擇行動裝置和社群軟體。

(5) 科技支援和教學法支援。

(6) 創造持續的互動，促進教師和學生在學習本體主導角色。

2.2 適性化的學習

依據 Brusilovsky（1998）對網際網路的適性化超媒體系統（Adaptive Hypermedia systems）使用方式所進行的歸納，認為數位學習（E-learning）主要分為兩個類型：適性化呈現（Adaptive Presentation）和適性化導覽（Adaptive Navigation Support）。「適性化學習」根據 IEEE Adaptive Instructional System 工作組（AIS）定義，主在於追踪學習者在問題解決過程中所收集到的相關數據資訊，能藉由動態性的改變，提供學習者所需的資訊與回饋，以便更適應學生的學習。企業培訓的技能與一般學校學習的知識理解有所不同，網路時代的興起，讓人們學習的腳步變得短而快。員工學習與工作界線也變得模糊，企業培訓員工

的工作技能必須與事業績效達成一致性關係，適性化的學習標準在企業提升員工的競爭力與工作效能上，是必要而不可或缺的。Kuo 和 Chang（2007）認為一個完整的適性化學習則需涵蓋學習過程的所有三個階段（同化、固化和應用）。以下說明適性化學習（同化、固化、應用）的基本概念 （如圖 1） 。

圖 1. 適性化學習基本概念圖

同化（Assimilation）是指當學習者學習到一個新知識，學習者必須將該知識與本身既有認知作連結，才能真正學習到新知識。所以學習者對於新知識的接受度，與他先驗知識能力有密切相關。而當學習者無法達成知識的認知就會產生學習焦慮與乏味效應。這時便必須透過輔助等機制來引導學習者完成任務學習。俄羅斯心理學家 Vygotsky （1978）提出「近側發展區間」（Zone of Proximal Development ， ZPD）心智關係圖(如圖 2)，其中說明學習是否能夠完成學習任務必須發生在 ZPD 的區域內。而遊戲學習設計的目標是要讓玩家一直保持在「近側發展區間」的學習通道（Flow Channel）內，當玩家透過不同經歷或技能的提升，慢慢往高技能及高難度的方向挑戰，期間因為挫折與難度克服所產生 Z 字型前進，這是因為過程中「容易值」與「難度值」不斷變更及交替的結果。Vygotsky 聲稱所有的學習都需發生在 ZPD 內，更認為 ZPD 區域外的學習不能算是學習。 其原因在於超出「近側發展區間」且處於乏味區的學習活動，學習者的學習是他已經了解的知識；而處在焦慮區，學習任務失敗或不完整（例如沒能通過評量）等於學習沒有完成。

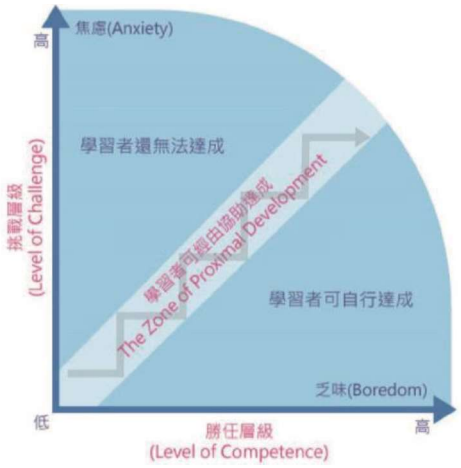

圖 2. ZPD 學習心智圖

Melton（1963）認為記憶分為三個階段，編碼（Encoding）、存儲（Storage）和提取（Retrieval）。每當訊息被注意到，首先會以短期記憶方式暫時儲存在觀者大腦中，然後需經過固化（Consolidation），固化是鞏固知識過程來形成長期的記憶。固化的重點在於當學習者初次獲得新的訊息、知識、技能之後，經由不斷複習或練習來強化記憶與技能精熟。而當學習有所遺漏時，適性化系統透過固化方式（如何時復習、複習量的多寡等）來達成長期記憶目標。而數位時代的來臨，讓處理固化知識的能力，交由智能機械來達成也變得容易，而固化的行動學習中也常用評量方式來達成。企業培訓中的固化包含以下三種範例。碎片時間：安排適當時間所進行的重複學習活動、社群學習：推薦與學習者有正向關係或學習相匹配的同學所進行的社交學習活動、穿戴裝置：運用在工廠實作上，透過穿戴裝置或行動裝置所進行的學習活動。

應用（Application）是將接受到的知識和技能，能夠實現在工作場域運用。企業學習場景的目標是事業績效。良好的企業培訓計劃應該定義出學習者崗位能力模型，再對平日可以由工作實際需求驅動學習，學習系統必須能支持學習者學習任務的工作需求，並進行關聯數據收集，最後達成工作崗位之任務完成和解決問題的實踐。而在本計畫中，主要發展在同化與固化的滿意度研究，對於職場的應用，則期許未來可加入到更多實際工作場域研究。

2.3 圖文冗餘

冗餘現象產生在 Mayer 和 Anderson（1992）的實驗中被提及，當時通過雙通道的多媒體實驗（Dual-channel theory of multimedia learning）發現（Kim, 2006 & Paivio, 2014），文字（On-screen text）與圖像（Picture）

同時並存於單一視覺通道時，容易發生視覺過載，進而造成學習者分散注意力，降低學習成效。實驗中，學習者如果放棄文字（On-screen text）訊息或忽略文字，把文字只是輔助項目，學習者仍可只觀察圖像或動畫的視覺訊息，並藉由聽覺通道（Audio channel）獲得完整訊息，冗餘現象產生但造成干擾並非明顯。在本研究中，從互動文字提示與動畫的搭配，理解文字與圖像依存的關係，這相關到動畫在多媒體教學上的七個原則，其中空間連續原則（Spatial Contiguity Principle）認為分開文字與動畫的位置越遠，學習者需花費工多精神找尋兩者關係，所產生干擾也越大（Mayer & Lonn, 2001；Mayer et al., 2002）。

3 研究方法

3.1 研究設計

本研究以空中巴士 A330 客機的檢修訓練，並針對剎車器的安裝模擬為例，進行在行動學習的研究。研究採實驗法與半結構式訪談法，分別進行對使用者滿意度與開發者的訪談調查。研究主分為二個部分：第一部分是「行動學習滿意度調查」，透過學習動機與學習興趣的表現，理解行動學習策略發展在成人教育上的同化與固化成效。第二部分則為「媒材特徵差異比較」，對照「互動安排結合 3D 動畫」（簡稱 3D 互動）與「影片記錄媒材」的差異，包含「媒材取代性」及「3D 互動圖文冗餘」的調查。研究使用量表以參考陳昱宏和王偉丞（2021）的認知（對學科的學習態度）、情意（對學科的自我感受）、技能（對學科的投入與練習）學習量表，該研究認為學習動機與學習興趣對引發學生持續投入學習的興趣與意願有正向的影響。我們將使用者滿意度調查量表分為三個向度並安排十一項目因子（如表 1）。三個向度包含教材設計面（認知）、媒體展示面（情意）、互動介面安排面（技能）。教材設計面主要理解教材發展是否具近側發展區間（ZPD）的同化（Assimilation）表現，該面向主要呈現教材規劃的簡潔、條理與資訊正確。而對於媒體展示面則以動畫情態影響學習感受，包含動畫吸引度、媒體取代等因子的調查。互動介面安排面則對於互動控制的回饋表現與圖文冗餘調查，其反應在使用者可重複練習的固化學習效益。以上因子則分別透過行動學習的三個模式（教育、訓練、考測）呈現。

3.2 研究工具

為符合大規模的人員培訓及降低企業購買昂貴的頭戴設備成本。飛機檢修的行動學習開發主以一般平板裝置，並透過應用程式下載方式，讓使用者不須在特定工作現場的環境，便可運用擴增實境同步定位與地圖構建技術（Simultaneous localization and mapping，SLAM）（Piao, 2019）建構虛擬場景。此無標記（Markerless tracking）的追蹤方式，讓使用者透過本身位置移動與平板內的 3D 物件產生互動，藉以達到混合實境的體驗。當 3D 物件在空間被定位後，使用者透過平板鏡頭可近距離觀察到特定物件，也可移動平板至遠距離觀察 3D 物件，此方式可模擬工作現場的環境視效也不須真實物件輔助才能達成。雖然平板裝置無法達到完全的沈浸體驗，卻能具備遊戲感觀的虛擬情境表現。而在學習內容上，規劃以 16 步驟的平板電腦學習單元，每一單元須讓

表 1. 三個向度十一項目因子

向度因子	權重值	項目因子
教材設計（認知）	0.3	內容正確性
		內容組織是否具條理
		替代傳統教學可能性
媒體展示（情意）	0.4	虛擬實境動畫表現是否具吸引度
		虛擬實境動畫表現是否正確傳達資訊
		虛擬實境動畫表現是否可替代影片媒材
		虛擬實境動畫在圖文整合上是否有冗餘現象
互動介面安排（技能）	0.3	介面閱讀舒適性
		介面安排的合理性
		圖文與音效整合的適切性
		互動操控是否順暢

使用者記憶操作工具、操作位置及操作步驟。研究對象以未接受任何飛機檢修經驗的 18 歲以上成人為主，並排除具先驗學習經驗的使用者。我們依照李克特氏五點量表（Likert scale）方式，再經由每個向度提出 3-4 項的使用者滿意度回饋調查。33 位學員接受影片學習與 3D 動畫模擬兩組比較，研究分為控制變項與自變項。控制變項：章節單元、操作工具、操作項目，介面安排；自變項：影片學習（教育模式）與 3D 動畫模擬（訓練模式）。專家訪談則從參與本次規劃與執行的設計者中挑選（業界 2 位、學界 3 位），針對教材設計與媒體特徵的侷限性進行意見統整與討論。

3.3 教學設計

以華航飛機檢修紙本教材進行轉化，內容以維修人員在實際工作場域進行剎車器的安裝的教育訓練單元，透過 16 單元的規劃，學員必須能夠從每一單元中對工具的選擇、工具操作位置、工具操作方式及操作順序都能清楚理解與記憶。我們依照 Richard（1999）企業教導訓（JIT）練的準則規劃內容，並分別透過「教學模式」、「訓練模式」、和「考測模式」三項模式進行。每一單元安排 4-5 項記憶重點與提示，我們使用傳統紙牌連連看的遊戲邏輯再結合到任務導向的互動設計，讓使用者能透過上下文連結建構宏觀的心像記憶。

3.3.1 傳統影片教學模式

對照組的教學模式安排：我們在「教學模式」安排傳統影片教學，影片為工作現場的技師實地操作的錄影片段紀實。影片未經教學設計的剪輯與段落安排，摻雜部分或未經整理的工作紀實，影片長短不一，也未加入解說與旁白提式，藉以呈現原始的實況錄影。此「教學模式」內容涵蓋「完整操作」、「上煞車」、「拉拉操作」、「裝煞車液壓管」、「潤滑油劑」及「安裝電器接頭」六項影片。此對照組使用在「媒體特徵差異比較」項目，用來比較經過教學設計的 3D 模擬媒材與傳統錄影媒材在使用興趣上差異。

3.3.2 3D 互動融入行動學習的教學模式

實驗組的教學模式規劃：此模式安排在「訓練模式」、和「考測模式」之中，屬「媒體展示」及「互動介面安排」構面，其項目如「單元摘要提示」、「工具目錄選單添加」、「圖文提示」、「動畫模擬」、「錯誤提醒」、「回播」、「分數獎勵」等，我們導入 ADDIE 教育模式（需求評量、課程設計、發展教材、施行、評估），讓學習者透過教材施測後能進行學習成效追蹤（Branch, 2009）。在此模式下，我們對混合實境 3D 動畫展示的滿意度進行施測。而在「媒體特徵差異比較」項目，則對照「教學模式」中的影片教材，進行媒材特性的比較與施測。訓練系統平台的教學策略包含（如圖 3）：

I、 系統規劃，II、互動設計安排，III、動畫模擬，VI、評量設計四項。

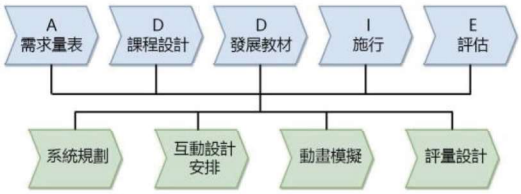

圖 3. 訓練系統教學策略

3.3.3 系統規劃

依照適性化學習標準，一個完整的學習，必須包含同化、固化及應用的三階段完成，才能達到有效的學習。行動學習開發以認知理論中同化與固化的學習基礎，並強化在結構化、問題解決與最好的學習方式所進行教材編撰。課程導入並依照 Richard（1999）企業教導訓（JIT）練的準則，其包含(1) 教材計劃(Get ready to instruct)、(2) 使用導向的教材準備(Prepare the Learner)、(3)教材展示方法(Present the learning)、(4) 評量與再訓練(Try out learning performance)、(5) 驗證成效(Follow up)。而這樣的標準可符合到大量產線製造、並提升員工學習動機、加速學習腳步與容易學習等特性。以下為教學策略的發展概念圖（如圖 4）。

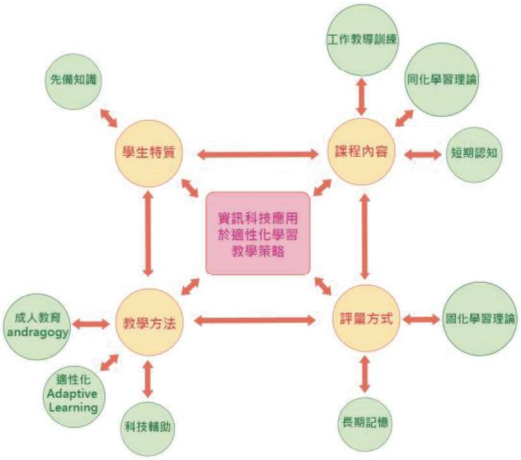

圖 4. 教學策略的發展概念圖

(1) 教材計畫：紙本教材需進行數位轉化並在 3D 虛擬環境中做即時的展示，但由於虛擬環境不易呈現紙本教材中的高級組織概念（Advanced Organize）。因此教材計畫須透過介面安排，適當提供目錄訊息，作為使用者對上下文資訊的理解。高級組織概念是 Ausubel（1968）提出，認為前導組體的功能是提供一個觀念架構，使學習者對於即將學習的「較細節性」和「較分化性」的教材能更穩固的結合和維持。該高級組織是在學習之前呈現的信息，學習者可以使用它來組織和解釋新的傳入信息。因此互動介面安排須有層級概念，才能讓使用者可更易理解整體操作概念。

(2) 使用導向的教材準備：在使用者導向的訓練上，我們安排使用者透過遊戲中的任務導向及簡單的連連看遊戲邏輯作為互動機制，減少使用者需花太多時間在介面操作使用上的學習焦慮。所有工具透過圖像符號設計並展示於使用介面中。學員可以用一對一的對應方式，連結虛擬場景的相關物件並了解其用途。任務導向讓使用者在每一單元中，透過程序模仿來理解操作的內容。

(3) 教材展示方法：使用擴增實境即時定位與地圖建構（SLAM）功能，代替只能單一視角的虛擬實境 3D 展示，擴增實境技術具備 SIFT（(Scale-invariant feature transform）特徵，尺度不變特徵是計算機視覺中的一種特徵檢測算法，用於檢測和描述圖像中的局部特徵（Lowe, 2004）。這方便使用者透過現實環境偵測來固定虛擬場景，並讓使用者透過移動鏡頭來達成目標位置觀察。相較於固定鏡頭的 3D 虛擬展示，使用 SLAM 技術更容易幫學習者理解現實場景的比例與細微零件的觀察。而擴增實境技術另一特徵 SURF（Speeded-Up Robust Features）則具備作為輔助資訊及時提供上，其功用讓鏡頭目標能代表使用者所看暨所想，鏡頭目標點必須即時提供使用者想要資訊（Bay, 2008）。

(4) 評量與再訓練：考測模式在不提供輔助訊息提示鷹架下，學習者須單獨完成單向的線性步驟，並以工具對應目標物的方式作為給分機制。學員須選取正確工具並點選到正確的操作位置才給分。行動學習強調在過程的理解與記憶，而非目標的達成。這與一般的任務型遊戲機制強調在快速到達目標是有所不同，就如同地圖導航主要輔助使用者可正確到達目的位置，但並不一定能讓使用者記憶所有路徑與過程。

(5) 驗證成效：考測模式中使用者須登入帳號，透過 Firebase 的網路服務平台，系統後台能夠統計使用者的學習分數並追蹤的學習狀況。藉以符合到 ADDIE 教學策略發展。

3.3.4 互動設計安排

對於飛機檢修行動學習上的應用，系統透過互動介面在不同圖層的管控，例如輔助說明圖層顯示、語音導覽選項和文字說明輔助的即時互動參與等，達成呈現不同組織與學習狀態的互動設計（Molnár, 2018）。3D 物件呈現以工具機內容及手勢輔助提示為主，期間如遇操作正確或錯誤，皆有語音回饋提示，而在工具解說上，以鏡頭中心點的指標靠近（Rollover）產生跳出式輔助視窗來達成進階說明的多圖層展示。而在評量回饋方面，根據使用者答對與答錯的題數作為驗證標準。整體展示儘量透過圖像符號與輔助指標指引來簡化文字訊息，並減少過多文字訊息所造成視覺的冗餘及閱讀干擾。介面內容避免產生與教學不相關的圖案或過度裝飾的繪圖。最後尋求內容正確性與情境化目標達成。以下為互動視窗介面圖例（如圖 5）。

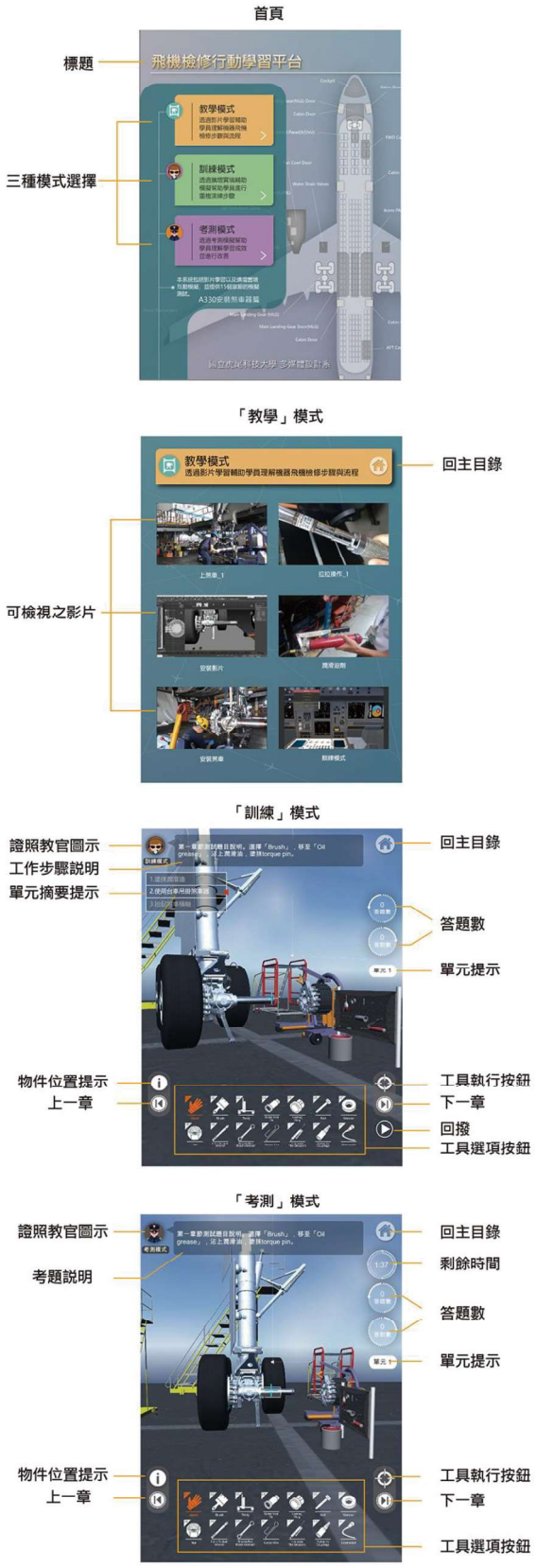

圖 5. 互動視窗介面圖例

本系統開發主要以 Unity 遊戲引擎作為 3D 展示平台，Unity 是一個支援多平台輸出的互動式的遊戲開發工具，它包含了最強而有力的引擎可充分地聯合各方面專業技術，並實現真正即時 3D 環境渲染。而在混合實境互動上使用 AR Foundation 套件及 iPad 平板裝置，讓使用者更具臨場效果。程式編撰以 C#及 Dotween 套件搭配，模型以 3ds Max 軟體進行 3D 動畫編輯與模型製作。為搭配多人協作與平台整合，我們使用 Atlassian 所開發的 SourceTree 免費 Git GUI 來進行專案控管及版本同步，並透過 github 的線上服務進行分享。以下為互動設計架構圖分析。以下為系統平台的架構流程（如圖 6）。

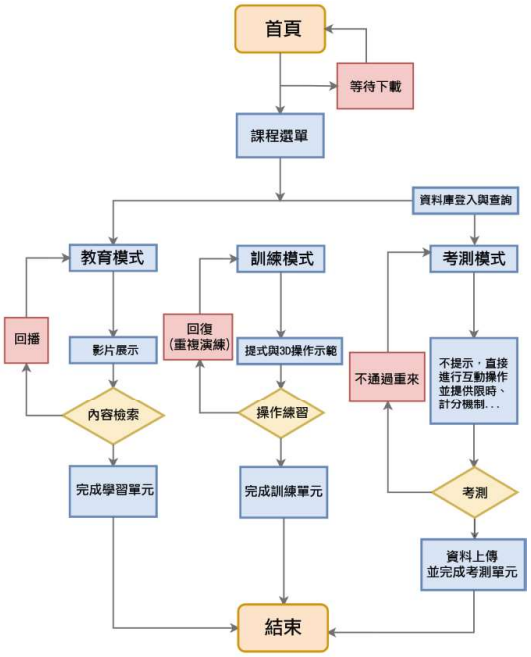

圖 6.系統平台的架構流程

3.3.5 動畫模擬

3D 動畫內容以模擬飛機檢修須注意的工業安全防範及機具操作的處理方法為主。場景物件展示以手勢搭配機具操作的無死角觀察為重點，故事訴求強調手部操作動畫安排及小片段工作完成示範為主。

3.3.6 評量設計

考測模式可透過 Firebase 資料登入，追蹤學習狀況。系統可顯示並比對考生前後次學習狀況與排名。以下為使用者資料登入畫面圖示（如圖 7）。

圖 7. 使用者資料登入畫面圖示

3.3.7 實驗流程架構

本研究採實驗法與半結構式訪談並行方式，透過「半結構式訪談」的質性探索與搭配「實驗法問卷調查」的量化比對，藉以獲得較全面性的有效樣本評估。

實驗工具主以手持式平板電腦為主，搭配飛機檢修行動學習 APP 下載，使用者可在任何場地下透過擴增實境定位技術（SLAM）進行互動學習。本研究依照飛機檢修在安裝煞車器所進行的模擬教學，內容分為 16 個單元，再透過影片導覽、3D 互動模擬及考測模式來驗證使用者學習成效，測試者在打開行動學習軟體後，進入在首頁項目包含教學、訓練及考測三項進行示範，初學者可先行點選教學模式，該項目透過影片學習，藉以理解安裝煞車器的實際操作項目，然後再透過訓練模式，進行單元分類以及重點方式的提醒，並以任務導向以及連連看的遊戲邏輯，讓使用者能夠按照提示或重複示範，一步步完成操作示範，並以加強記憶連結。考測模式可透過資料登入，追蹤學習狀況（如圖 8）。

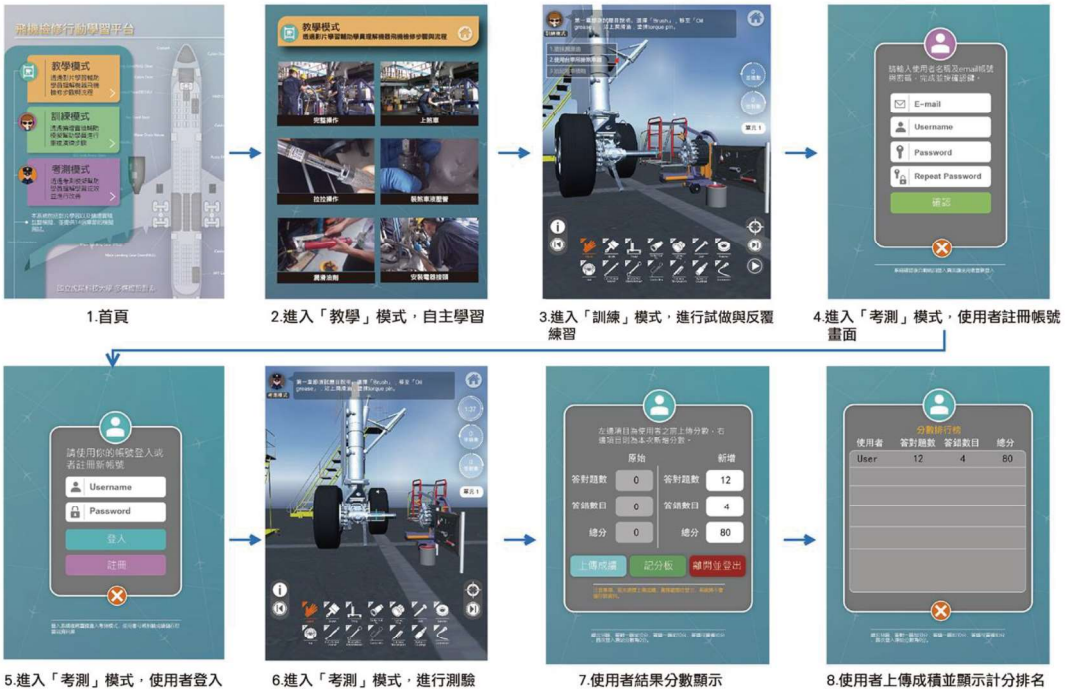

圖 8. 學習步驟說明

4 研究結果

研究針對「行動學習滿意度調查」與「媒材特徵的差異比較」的問卷調查進行敘述統計

分析，並從單一樣本、獨立樣本與成對樣本 t 檢定中，觀察三個構面之相關顯著性影響。

4.1 統計分析

(1) 「行動學習滿意度調查」：

以下依照認知、情意、技能三個構面的表現上進行說明。本次實驗從 33 位受測者的調查顯示，三個構面（認知、情意、技能）在 Cronbach’s Alpha 值為 0.746，顯著性<0.05 具顯著性，認知構面的平均值在 3.42、情意構面的平均值在 3.68，技能構面的平均值在 3.87，三者皆於 3 以上，顯示本次問卷資料具有足夠的信度與效度表現（如表 2）。

表 2. 三個構面的描述統計

項目	檢定值 = 3			
	t	自由度	顯著性	平均差異
認知構面	3.799	32	.001*	.424
情意構面	7.226	32	.000*	.686
技能構面	10.122	32	.000*	.878

註； *表 p<0.05，有顯著差異

而在三個構面的成對樣本 t 檢定中顯示，認知構面與技能構面成對的顯著性為 0.000，顯示互動介面安排對教材認知的影響性較媒體展示對其他構面的影響更為顯著（如表 3）。

表 3. 三個構面成對樣本檢定

項目	t	自由度	顯著性 (雙尾)
認知構面-情意構面	-2.567	32	.015
情意構面-技能構面	-2.041	32	.050
認知構面-技能構面	-4.531	32	.000*

註； *表 p<0.05，有顯著差異

認知構面：該項反映使用者對行動學習教材的理解，其相關到教材設計的同化與固化表現。問卷項目包含：1.是否了解教材步驟重點（平均數 3.61）、2.是否可按步驟操作示範內容（平均數 3.45)及 3.從互動文字提示是否了解工具名稱與用途（平均數 3.21）。其中 1 與 2 項較為顯著，此項內容顯示使用者普遍能理解 3D 互動的訊息並獲得記憶與執行步驟，而對於了解工具名稱與用途部分則較其他稍低，其反映使用者在 3D 互動中對文字閱讀能力表現較弱（如表 4）。認知構面主要理解教材規劃的簡潔、條理與資訊正確，讓使用者能清楚理解步驟的重點，進而記得步驟並進行操作示範，且符合近側發展區間（ZPD）的表現。

表 4. 認知構面的描述統計

項目	個數	平均數	標準差
1.你是否了解步驟重點	33	3.61	.659
2.你是否可按步驟操作示範內容	33	3.45	.833
3.從文字提示是否了解工具名稱與用途	33	3.21	.740

情意構面：該項反映使用者對媒體展示（3D 動畫）面向的興趣與喜好，其相關到媒體展示的同化表現。問卷項目包含：1.是否滿意 3D 展示的語意表達、2.不透過語音下是否理解 3D 操作表現及 3. 3D 互動表現可取代影片媒體教學。從描述統計中發現，透過 3D 互動展示，使用者普遍理解教材示範（平均數 3.55）及語意表達（平均數 3.82），且認為 3D 互動有較佳的吸引性並有取代影片媒材可能（平均數 3.70），並對 3D 動畫呈現感到新奇（如表 5）。

表 5. 情意構面的描述統計

項目	個數	平均數	標準差
1.是否滿意 3D 展示的語意表達	33	3.82	.683
2.在不透過語音是否理解 3D 操作表現	33	3.55	.833
3.3D 互動表現可取代影片媒體教學	33	3.70	.770

技能構面：該項反映使用者對互動介面安排的滿意度調查。其相關到介面互動功能與回饋在固化表現。內容包含：1.輔助文字與指標是否吸引使用者注意畫面內容、2.是否滿意互動安排的多元視角功能（環境理解）及 3.多媒體互動文字展示是否助於教材內容理解。從技能構面表現觀察，明顯優於其他。顯示混合實境的互動設計安排在透過輔助指引等功能下，有強化資訊及幫助理解的能力。而多元視角的即時互動，讓使用者可重複觀察學習對象，觀者更容易透過互動達成對知識理解與記憶（平均數 3.85）（如表 6）。

表 6. 技能構面的描述統計

項目	個數	平均數	標準差
1. 輔助文字與指標是否吸引使用者注意畫面內容	33	3.73	.674
2. 是否滿意互動安排的多元視角功能	33	4.06	.609
3. 多媒體互動文字展示是否助於教材內容理解	33	3.85	.870

(2) 媒材特徵的差異比較：

該項目比較「互動安排結合 3D 動畫」與「影片記錄媒材」的差異，包含「媒材取代性」及「3D 互動圖文冗餘」的調查。「媒材取代性」：從對照組與實驗組的平均數比較中發現，A.「不透過語音說明是否滿意 3D 互動表現」的平均數 3.55 高於 B.「再不透過語音說明你是否能從影片中理解工程師的操作過程」平均數 2.82。在去除聲音通道的輔助下，3D 互動有優於影片展示方式及取代影片媒體可能。而在媒體取代性的問卷項目，使用者普遍認同 C.「3D 互動表現可取代影片教學」，其平均數也相對高於其他（如表 7）。

表 7. 媒材特徵的差異比較

項目	個數	平均數	標準差
A. 不透過語音說明是否滿意3D互動表現(實驗組)	33	3.55	.833
B. 再不透過語音說明你是否能從影片中理解工程師的操作過程(對照組)	33	2.82	.983
C. 3D 互動表現可取代影片教學	33	3.70	.770

成對樣本檢定	t	自由度	顯著性(雙尾)
（實驗組 A）-（對照組 B）	-4.423	32	.000*

註： *表 p<0.05，有顯著差異

而對於問卷「3D 互動圖文冗餘」的觀察上，在「兩組展示中有文字說明跟沒有文字說明」的調查中，偏向「有文字說明」比較清楚占 23 位，認為「沒有文字說明」比較清楚占 10 位。使用者普遍還是認為互動文字有輔助說明與認知功用。而對於「文字影響注意力」方面，從獨立樣本 T 檢定中，針對 a：「兩組展示中有文字說明跟沒有文字說明」與 b：「過多的文字是否造成注意力分散」的兩個項目分析上發現，認為對過多文字會造成注意力分散的學員，傾向選擇喜歡沒有文字的圖像閱讀方式（平均數 4.50，顯著性 0.001）（如表 8）。

表 8. 過多的文字是否造成注意力分散

a.兩組展示中「有文字說明」與「沒有文字說明」，哪組對使用者有比較清楚的訊息展示	個數	平均數	標準差	平均數的標準誤
有文字說明	23	3.65	.573	.119
沒有文字說明	10	4.50	.707	.224

獨立樣本 T 檢定

	變異數相等的 Levene 檢定		平均數相等的 t 檢定						
b.過多的文字是否造成注意力分散	F 檢定	顯著性	t	自由度	顯著性(雙尾)	平均差異	標準誤差異	差異的 95% 信賴區間	
								下界	上界
假設變異數相等	.816	.373	-3.641	31	.001*	-.848	.233	-1.323	-.373
不假設變異數相等			-3.344	14.388	.005*	.848	.254	-1.390	-.305

註： *表 p<0.05，有顯著差異

4.2 訪談與意見回饋

針對「行動學習滿意度調查」在「半結構式訪談」中，從認知構面的教材設計上專家看法，普遍認為須考量互動邏輯的目的，過度注重任務導向或遊戲導向，容易讓使用者分心，進而造成片段的記憶學習。而對於情意構面的媒體展示訪談中，認為透過混合實境在使用者主動選取視角的情況下，如何不讓使用者視角不偏離主題,需要更多輔助性誘導。而從技能構面的互動設計安排項目訪談中，認為 3D 動畫已成為在混合實境中，轉化訊息與傳遞訊息的重要媒介。另外在「媒材特徵的差異比較」上，五位開發者持不同意見，認為 3D 互動無法完全取代影片教學。其原因認為 3D 互動屬「模擬媒材」，教材在經過優化過程，與原始紀實錄影的方式有所不同，較難做到客觀陳述。而對於運動技能的呈現，以目前 3D 模擬技術較難克服的運動技能細微表現（Fined Motor skill），可能須借助更多的回饋裝置輔助才能達到運動技能模擬。而使用者則認為，從訊息傳達的內容正確性角度上來看，互動安排結合 3D 動畫展示具備取代影片教學的可能。而在「3D 互動圖文冗餘」的專家訪談調查上，普遍認為圖文整合的互動方式是 3D 互動不可或缺的要項，利用符號與動畫連續性等原則，可有效降低過度依賴文字展示的閱讀型態，達成減少文字冗餘並加速在認知與記憶學習上。

根據幾位開發者的訪談中發現，互動安排結合 3D 動畫表現有優於影片媒材的吸引性，但對於透過 3D 互動或影片方式學習，取決在教材設計而非媒體特徵。以下歸納幾個意見重點。

(a) 影片媒材及動畫媒材各自有其媒體特色。透過影片媒材可包含正確的環境紀錄及接近實境的環境展示，具有接近現實的親和力。而 3D 互動則在重點提示與簡化內容上有較佳表現。行動學習的效果不管在群體的量化調查與個案訪談中，都有一致性的滿意度。

(b) 對於行動學習是否能取代傳統教學和紙本教材的可能性上，受測者都站在保留的態度，認為互動回饋能力以及教材規劃的妥善性必須達到一定水平，才有可能取代傳統教學。

(c) 對於行動學習站在輔助學習的角度上，開發者普遍持正向的肯定。並且認為互動媒材與影片媒材因特性不同具備相輔相成的效果。

(d) 混合實境對於理解實體物件與環境空間具有較佳的表現，但由於軟硬體的載具不同(輸入裝置的限制)，在操作方法上沒有一定標準，對初學者容易產生學習焦慮。

(e) 混合實境具有互動優勢，但前提必須有良好的沉浸感和擬真感。時間成本效益都應一併考量。

5 結論與建議

從研究發現使用混合實境作為行動學習的表現，對於同化與固化的適性化策略，使用在 3D 互動的輔助下有其優勢。混合實境保有接近真實尺度的模擬及疊加資訊的即時同步優勢，這幫助我們更容易理解環境現實及快速取得資訊的能力。而強化在媒體特性的控管，也將是行動學習不可忽視的要項。

在訓練模式的學習階段中，教材與程式設計保有更多的使用者探索及自主學習期待。針對互動學習所產生的焦慮、興奮、無聊等因子控管大多來自於使用者科技素養與預測互動邏輯程度不同所產生的排斥有關。因此學習的有效不只在學習過程的有趣，還牽涉到互動機智設計、故事順序流程規劃、美學介面引導及互動功能的技術實現，也才有可能達成邊玩邊學的學習形式。

課程設計：行動教學在紙本教材內容轉化上獲得了什麼樣的提升或者損失在互動設計本身俱有重要的象徵指標，不能只重視數位內容的優點和忽略了在教材轉換上的遺漏與缺失，並儘可能從不同媒體形態的展示上去補足這些不足。譬如 3D 模擬的特性較困難真實呈現運動技能的細微特徵，此時可藉由影片錄影型態的輔助，達到相輔相成效益。

文本教材內容轉換：針對工業教育訓練模擬，本研究限縮在使用者的操作記憶訓練，因此可以減少對於需要更多的互動溝通與問題解決思考的面向上。當互動溝通的相互依賴降低，便可落實在情境模擬與實際課程設計上對應的差異，以及作為教學輔具上所具備的補充學習環境的不足，並免掉落於替代學習所產生的無可取代性。在行動學習教具開發上，對於文本的內容不容易有具體統整的架構的方式呈現在 3D 虛擬環境中，也容易被課程設計所忽略。如同道路導航設備，因其任務導向在輔助駕駛專注於路況，進而降低了路徑過程記憶，這明顯與強調記憶學習導向的設計不同，

對使用者來說，過多瑣碎細節與缺乏先進組織目錄架構，都可能造成記憶無法存放及無法放棄鷹架而自主運作。因此一個有效的文本教材，可透過教師的精心設計與安排，歸納完整的訊息內容並透過先進組織的概念(其中包含如目錄、摘要、重點提示、圖表輔助等筆記重點)，仍有其不可取代的價值。但也容易造成學習上的倦怠。

站在行動學習要求上，教材設計必須優先於媒體特徵考量，甚至有一致性的規範。而課程發展的策略上，更應著重目錄層級的分類概念，並透過在混合實境中目標位置、工具位置環境理解的三要素建立有利於使用者心向目錄建構，並實際發展於介面的圖示與展示架構上。

互動設計安排：真實世界多元複雜，3D虛擬空間在模擬現實時，使用者容易透過任何角度觀察事物，因此不容易建構一個具單向的線性連結，透過介面安排與特定的章節順序來強化視覺上重點便成必要。但混合實境可發揮其無所不在的觀察，讓使用者擁有更多探索與期待。反觀在遊戲設計中，過多的視覺效果可能消耗使用者能量；而在行動學習中，則儘量簡化資訊並避免冗餘，其目的有所不同。如從讓學習更輕鬆的角度上，遊戲設計與行動學習不應等同視之。

對於一個現在充滿數位輔助學習的時代來臨，數位學習的功效，往往被過度放大。從以上實驗可以了解到行動學習有其特定價值，但當課程原始期待無法被鞏固時，行動學習是否與傳統教具有著巨大的落差，在某些層面上是值得商榷。本研究也試著從行動學習互動的優缺點上，理解互動設計的製程與課程邏輯之間的相關聯，並找出最適當的設計方法。尤其在工業教育訓練的領域中，期許行動學習在透過製程與課程的優化，能達成重複性與擴充性的教材推廣價值。

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學術資訊視覺化網路系統的建立與應用-以WOCAD學術資料庫為例

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摘要

學術資料通常包含了數億個原始數據，而這樣大量的資料該如何有效進行分析並檢索出有效的訊息是研究者面臨的關鍵問題。資訊視覺化作為一種研究方法，常被用於幫助理解數據之間的關係，有效的視覺化內容甚至可以為解決問題提供見解。因此，本研究以 WOCAD (Web of CAADRIA) 資料庫作為數據來源，該數據庫是來自 CAADRIA 會議 1996-2015 年的精煉關係數據。由於 CAADRIA 作為電腦輔助設計 (CAD) 中的一個特殊興趣小組 (SIG) 的性質並針對此單一領域做知識的累積及拓展，這些數據提供了不同於一般學術資訊的領域特定信息且非常適合表現在該領域中的意義。本視覺化網路系統使用 D3.js 做為學術資訊視覺化呈現的開發工具來繪製視覺圖，並建立了 MEAN Stack 介面系統來管控及調整 MongoDB 的資料內容，最後透過此系統所製作的視覺圖來做比較分析。視覺化研究透過了作者、著作及關鍵字的相互關聯以視覺化方式呈現，來讓研究者從中了解整個研討會的社交網路。本文以共同作者發表網路圖、關鍵字連結圖以及分年作者發表網路圖做比較與分析，從網路地圖中發掘作者的學術發展深度及拓展性以評價作者在 CAD 學術界的存在，並且評估作者在於學術圈中的活躍度與重要性，同時觀察作者於 CAD 領域中的發展脈絡。

關鍵詞：資訊視覺化、學術社交網路、數據分析、網路圖分析、D3.js

Developing an Academic Information Visualization Network System- using WOCAD academic database as an example

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ABSTRACT

The academic information often contains billions of raw data. How to retrieve a meaningful information from such massive amount of data effectively is a key issue for researchers. Information visualization as a research method is often used for understanding the relation and context among data, and effective visualization can even provide insights for resolution. Therefore, this article investigates an academic visualization network system with information visualization process. The data sources that this article uses is the WOCAD (Web of CAADRIA) database that is a refined relation data from CAADRIA proceedings from 1996-2015. With the nature of CAADRIA as a special interest group in computer aided design (CAD), this data provides a domain specific information that is different from the general academic information that is suitable for unleashing the meaning among this field. Visual network system conducted uses D3.js as a development tool for the visual presentation of academic information to draw

visual maps, and establishes a MEAN Stack interactive system to control and adjust the data content of MongoDB, and finally the visual maps produced is analyzed and results are compared. The interrelationship of authors, works, and keywords is presented as an interactive network visualization. From this network, the author's academic development depth and expansibility can be explored to evaluate the author's presence in the academic circle of CAD. The activity and importance of the author, while observing the author's development in the CAD field can then be unleashed and explored.

***Keywords*:** Data Visualization, Academic Social Networks, Data Analysis, Graph Analysis, D3.js.

1 研究背景

因網路的發展下學術資料的取得與分享普及，使得學術網已有數億筆的資料內容與學術知識。其中光是最大的學術網站 Google Scholar 就有近億筆的學術資料，而英文撰寫的學術文章就佔了絕大多數(Khabsa & Giles, 2014)。而學術資料的倍數成長下，學術數據的分析及視覺化成為了學術界與業界的關注焦點。該如何將知識脈絡更清楚的呈現，讓研究者與產業界能藉此看到學術發展，是如今學術大數據下需要被研究的問題。而學術社交網路(Academic Social Network, ASN)是使用了學術本體與其關係連結形成複雜的學術網路，從作者及著作去尋找更多其他的關聯，如作者的所屬機構、學位、過去的著作、指導與合作對象等學術社交關係。以此來連結作者與著作的關係，運用此網路圖研究者可以調查及分析學術的背景、現狀及趨勢(Fu, Song, & Chiu, 2014)。因此，本研究以 ASN 的方式建立一套視覺化網路系統，以學術網路視覺化來呈現 WOCAD 學術資料的相互關聯，並挖掘與分析其中的學術脈絡與發展。

1.1 WOCAD 學術資料庫

WOCAD(Web of CADDRIA)學術資料庫是由 CumInCAD 學術數據庫將 CAADRIA 學術與作者資料數據庫相互結合，其特點在於只收錄電腦輔助設計(CAD)領域的論文進行知識疊加，並從此單一領域中找尋更多的發展可能，但其核心還是針對 CAD 領域來做學術發展。在近年電腦發展下電腦輔助設計成長快速，WOCAD 數據庫在累積的二十年間此一領域有著很大的轉變，因此在此資料中能夠探索到明顯的學術脈絡與變化。CumInCAD 是由 Bob Martens 與 Ziga Turk 於 1998 年設計及創建，收錄了有關 CAD 及同級協會歷年累計的出版物，通過數據庫來達成網頁方式進行書目索引(Martens & Turk, 1999)。CAADRIA 為亞洲電腦輔助建築設計研究協會，為 CAD 的學者與專家提供論壇及研討會，以分享與聚集亞洲電腦輔助建築設計的知識(S. Huang & Chang, 2018)。

CumInCAD 在 IST SciX 一個科學訊息交換的歐盟項目中，得到介面上的提升及顯著的增強，並在 2016 年再次更新，將其資料庫開放訪問及瀏覽，開發出 CumInCAD 2.0 的雲部署系統，其開源瀏覽方便使用者在進行資訊視覺化的資料取得(Cerovsek & Martens, 2016; Martens, Bjoerk, & Turk, 2002)。而在近年也開始研究文本挖掘與文獻計量分析，去挖掘 CAADRIA 研討會中作者、文章及研討會定量與定性結果，以此統計及分析整個研討會歷年來的研究過程，利用視覺化提供給對 CAD 有興趣的研究人員、教育者與出版者(Cerovsek & Martens, 2020)。

本數據庫記錄從 1996 到 2015 年間，CAADRIA 研討會及 CumInCAD 數據庫中計算機輔助建築設計相關的研討會、期刊及著作等資料，包含 9378 篇著作、19040 位作者、24532 個關鍵字及 64312 篇文獻相關資料，如此龐大的資料庫難以用查看來挖掘其中的脈絡。因此研究將以資訊視覺化網路圖來呈現數據內容方式來解決，資訊視覺化是使用圖形化的方式清晰地呈現及分析大量的數據內容，在做數據分析及資料探勘時常會使用到此技術來輔助，從大數據中找到有效有用的資料，能夠以此依據來做分析及決策。

1.2 資訊視覺化

資訊視覺化常被使用在數據分析及數據科學上，而近年來更是被廣泛應用在各個領域之中。此技術被應用在許多分析、評估與預測中，其視覺化的數據呈現能夠以不同的角度來觀測，甚至發覺過去未曾發掘的問題，以及呈現未來的趨勢面。在網路發展快速下，大量的資料以數據形態被存放在網路上，各式各樣的資料都能在上面取得。而如今這些大數據的資料成為了解決商業與科學問題的絕佳工具，行銷產業可以透過消費及瀏覽數據來了解消費者行為、偏好及消費趨勢(Boone, Ganeshan, Jain, & Sanders, 2019)。而醫學界也使用大數據來處理 COVID-19 的問題，從過去的數據來找尋未來的解決方案(Wang, Ng, & Brook, 2020)。近年更是廣泛地使用此技術來進行基因學及生物學的研究，以視覺化的技術來解讀及分解

基因序列，並由電腦科學的運算解決問題(Goldman, Craft, Brooks, Zhu, & Haussler, 2018; Nusrat, Harbig, & Gehlenborg, 2019)。另外也能被拿來解決能源問題，由大量的用戶數據來進行行為分析，可用於預測需求、最佳化分佈電網配置以及能源生產優化(Zhang, Huang, & Bompard, 2018)。

數據分析能夠幫助使用者解決許多問題，但大量的數據需要先進的分析技術來提取有價值的訊息，無法進行有效利用終究無法產生其價值，而資訊視覺化正是提取數據的一個好方法，將數據藉由圖表來增加可讀性，挖掘難以被理解及判斷的資料內容。過去我們曾研究WOCAD 數據庫的本體視覺化，幫助研究人員快速了解 CAADRIA 學術網路的本體。在研究中使用 protégé 進行建構本體結構，並能夠以 SPARQL 查詢及呈現彼此間的相互關聯，而本體的結構能夠賦予一個資料多個屬性，因此在呈現一筆資料時，同時也會連結出其他資訊及內容。如（圖 1）中在作者的資料中，也會連到其著作、著作的共同作者、著作使用的關鍵字及使用的文獻等，其他被連結到的使性資訊(S. Huang & Chang, 2018)。

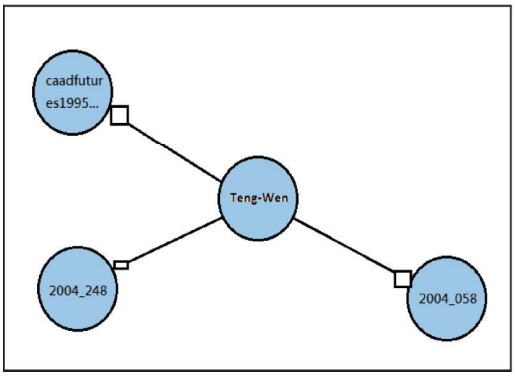

圖 1. 使用 SPARQL 查詢後的 ontology 呈現 (Huang & Chang, 2018)

另外，在之前的研究也曾以視覺化方法來分析設計過程，將設計過程轉化成資料型態，再以鏈接圖來挖掘設計過程中的交互影響。以放聲思考法來進行設計過程的記錄，並將每一個步驟及重點當作視覺圖中的每一個節點，最後以 Linkoghraphy 的方式製作連結圖表(Hsieh & Chang, 2017)。而這可以幫助設計師了解整個設計過程的脈絡，並挖掘出整個設計過程需要改善及解決的問題，以避免相同的錯誤發生(L.-C. Chen & Chou, 2018)。而另外也研究了團隊交流互動間的視覺化分析，以 Emoji 的形式創建社群的交流框架，將情感資料數據化以幫助進行情緒及互動分析(Y.-S. Wu & Chang, 2019)。

1.3 視覺化系統

資訊視覺化中的數據庫與視覺呈現需要統整成一個系統操作，能將數據的變化同步處理到視覺圖中。而在本實驗中使用 MongoDB 作為資料庫的存取系統，MongoDB 為 NOSQL 的資料庫類型，其特性為非關係型、分佈式及水平連結的，且能處理大量的非關係數據。這樣的方式與 SQL 的差別在於與關係數據庫不同，它可以有效的處理非結構化數據，如文檔、電子郵件與社群媒體(Ali, Shafique, Majeed, & Raza, 2019)。而其中兩者資料型態的比較性已有大量的文獻證明，在有大量用戶的論壇型應用程式，較適合以 NOSQL 的方式來建立資料庫(Győrödi, Győrödi, Pecherle, & Olah, 2015)。

使用 MongoDB 建立數據庫時，需要一個前台來控制及修正後臺數據，Node.js 可以快速的與 MongoDB 結合進行 Web 開發，而 MEAN Stack (MongoDB, Express.js, Angular, Node.js) 正是因此而建構的系統。MEAN Stack 是用於開發網站與網路應用的 JavaScript 開放原始碼套件，能夠將前後台的軟體進行整合，以 Node.js 的 npm (Node Package Manager) 套件來安裝 Angular、MongoDB 與 Express.js 後，Node.js 與 Express.js 可執行數據庫與前後端網頁的相互連結。其服務能讓在整個環境中都能以 JavaScript 語法進行編寫，過去使用 LAMP (Linux, Apache, MySQL, PHP)的方式進行操作，需要使用許多語法，且需要將 MySQL 的數據以 PHP 或是 Python 進行轉譯才可進到前端，這會使前端與後端連結變得複雜（圖 2）(Lotfy & Pyatt, 2018)。

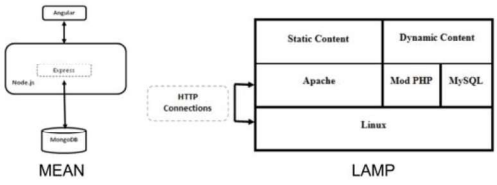

圖 2. MEAN 與 LAMP 的結構差異(Lotfy & Pyatt, 2018)

使用 MEAN Stack 的全端架構，可以讓前端與後端做系統性的連結，能夠更好的運用前端網頁去操控後端資料庫。而在資訊視覺化的過程中，需要同時管控前端呈現與後端資料，在展現視覺圖後仍然要做出修正，不只是顏色、粗細及大小等 CSS 的前端渲染編輯器調整，時常也要改變數據的資料及結構，才能在數據呈現出現問題時即時進行調整與修正。因此全

端的系統架構在資訊視覺化中起了很大的作用，讓視覺化呈現過程中能夠依照分析需求匯入及修改數據。

本研究旨在建置一套視覺化網路系統，來使學術數據庫中大量的學術資料能夠以視覺化方式呈現，以此來挖掘與探索學術脈絡並從中進行研究分析。在系統設計方面需要滿足大量的資料內容能夠被呈現在視覺圖中，且在操作數據分析時能靈活的改變資料結構與視覺圖外觀。因此使用 MEAN Stack 套件來幫助前後端能夠整合進行開發，在視覺化時能夠操作數據庫的資料。這能讓研究者更有效地從資料的關聯性中理解及分析數據，同時也幫助設計者在進行視覺圖製作時能使用此系統進行快速的修正。

2 文獻探討

為了建立一套資訊視覺化網路系統，並進行一系列視覺化測試，並從視覺化的圖形中找尋資料挖掘的可能性。因此，將從學術社交視覺化的分析方法進行探討，並使用此方法來執行視覺化圖形的製作。另外，也探討了視覺化的呈現方式以及視覺化的工具，來說明不同的視覺圖呈現所帶來的資訊差異，以及各種視覺化工具的所具有的功能及操作方式，從(1)學術資訊視覺化的分析方法(2)資訊視覺化圖形呈現及(3)視覺化工具這三個面向來進行討論。

2.1 學術社交視覺化網路分析

社交網路分析在許多領域發揮很大的作用，例如社交媒體網路、交通資訊網路及流行疾病學網路等，能夠利用這些視覺化網路圖來進行分析。該網路分析不只用於社交系統中，同時也提供學術領域的使用依據，像是在傳染疾病的防治中能扮演追蹤及判別的角色。學術社交網路(Academic Social Networks, ASN)因其資料量龐大且資訊不易整理，而近年來跨領域的合作增加，學術領域不僅限於在各自的範圍內，因此學術社交網路能幫助研究者了解當前的學術現狀與趨勢，也透過數據分析來挖掘學術網路的脈絡及可發展的面向及區域(Khan, Liu, Shakil, & Alam, 2017)。

學術社交網路分為同類型學術社交網路與相異類型學術社交網路，同類型學術社交網路的資料型態大致相同，通常為作者、著作、引用文獻及關鍵字等。而相異類型網路是大多數的學術社交網路(ASN)所使用的方式，為跨越不同類別的資料型態來進行連結，如（圖 3）將共同作者間再加入論文或是引文的元素，加以分析學者在學術研究上的發展與趨勢(Kong et al., 2019)。

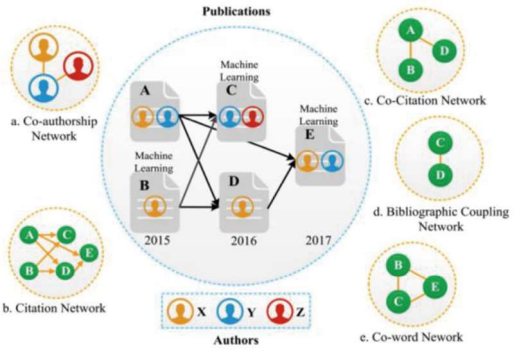

圖 3. 同類型學術社交網路資料型態(Kong, Shi, Yu, Liu, & Xia, 2019)

這類的數據形態所整理出的網路分為三大類：

第一類為協作網路(Co-Author Networks)，其連結發表著作及文章的共同作者，了解學者間的協作模式。這可以幫助研究人員了解知識傳遞的脈絡，查看知識是如何被接收以及傳遞出去。另外此舉也能當作評估學者的重要的程度的依據，藉由彼此間連結的父子關係找到傳遞的起點，亦或是知識的中心點。Masanori Fujita 等人提出一套分析法，於共同作者網絡的中介中心性，作為研究人員在科學技術發展和促進創新方面的循證評價指標，以此方法找尋知識的傳遞路徑（圖 4）。另外也通過此技術找尋具有前途性的新興研究員，其結果能有助於研究機構及其領域，能以此快速了解研究員的背景及特徵(Fujita, Inoue, & Terano, 2017; Fujita et al., 2018)。

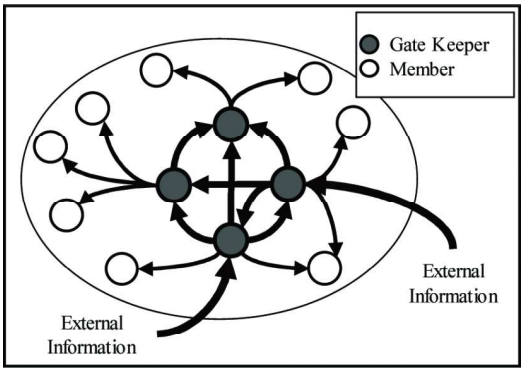

圖 4. 研究人員的知識關係圖(Fujita, Ishido, Inoue, & Terano, 2018)

第二類共引網路(Co-citation Networks)連

結著作所引用的文獻，能作為論文的計量依據。當作者引用特定文獻，其學術發表也將內化文獻一部分作為研究發展的依據，對於引用文本的學術想法與知識也做了更進一步的堆疊。而許多人引用同一篇文獻時，也將證明其學術是有一定的參考價值以及具有足夠的發展性。在Caleb M. Trujillo與Tammy M. Long的研究中，以視覺化的方式呈現共引網路圖，來分析跨領域研究的思維及脈絡，幫助研究者從文本共引的結構中辨識跨領域的思考方式(Trujillo & Long, 2018)。在視覺化圖表中以不同的圖標表示分類後的各別領域，另外藍色代表著目標文獻為中心拓展的思維網路。

第三類共詞網路(Co-Word Networks)連結共用關鍵字，可探索研究主題的趨勢及脈絡，但其命名沒有固定性，容易隨著時代而產生詞彙的變化。然而還是有許多使用共詞網路的文獻，關鍵字對於文獻探討主題及研究領域仍具有一定的識別性。而從共詞網路中找尋新興研究趨勢時，在使用上需要進行更多的分析。在關鍵字詞的語義上是零散的，因此要先做出結構性的整理，將關鍵字統整出領域分類，將頻率最高的字詞作為主題標籤，再從中判斷及預測(L. Huang et al., 2021; Katsurai & Ono, 2019)。

2.2 視覺圖的呈現

數據可以說是新時代非常有用處的資源，Bernstein的分析師Matti Littunen形容這些數據好比新石油，能夠有效利用及操作數據就能影響世界。許多科技巨頭也投資了大量的金錢在收集及彙整數據上，都想在這數位石油(digital oil)中佔據最有利的位置。而如此龐大的海量數據在被使用時常會遇到難以被解讀的問題，數據分析時包含了六個階段，(1)明確的目的及思路，在開始前需要充分了解視覺化目的，才能知道要蒐集哪些數據。(2)數據收集，能夠透過資料庫、網路資料以及實際調查等方式取得。(3)數據處理，包含資料清洗、資料轉化及資料提取等步驟，目的是得到乾淨可用的資料內容。(4)數據呈現，經常使用資訊視覺化的方式來展示，相對於文字與數字，圖表的型態更有利於人解讀及判斷。(6)評估與分析，將整個資料分析過程進行解讀後，得到一個明確的結論與問題的解決方案(Steele & Iliinsky, 2010)。

數據視覺化有非常多類型的圖表能夠呈現，常見的有樹狀圖、和弦圖、文字雲及力導向圖等，而這些圖表呈現的資訊也有所不同。該要取用哪個圖來作為展現，取決於數據的分類，很多圖表無法呈現出時間軸、相對位置或者類型等資訊。因此在選用圖表時，需要先確定選擇的數據以及要呈現出的內容，在視覺化時才能表現出重要的部分。然而，有些數據內容是複雜且難以理解，甚至需要在數據搜集時就進行分類來定義每筆資料及其使用的方法，因此在呈現視覺圖前必須明確的制定問題，以及如何解決才能判斷該使用何種類型的圖表來呈現內容(C.-H. Chen, 2020)。另外，現今資料的筆數需求量不斷地增加，在每一筆資料中還包含著許多屬性，來尋求數據分析能夠更加準確。因此在資訊視覺化時需要能呈現龐大數據資訊的視覺圖，在圖中需要涵蓋許多內容，但又不能太混雜使資料無法被分析判讀(Brath & Jonker, 2015)。在學術社交視覺化中，多使用網路圖(Network)來作為呈現，因其能夠完整的表現出大量的資料，且可以清楚的看到每一筆資料之間的關聯性。因此，主要採取此方式來作為視覺化的圖表呈現，並從視覺圖的分析中挖掘更深層的學術脈絡。

視覺圖呈現是為了讓人更快速的理解大量訊息並可從圖表中的內容進行分析，為了將資訊有系統的呈現於圖表中，設計者會從顏色、大小、標籤及位置等變量來做視覺圖設計，以此進行資料的分組幫助後續的分析。(Mithili Devi & Kasireddy, 2019)使用Gephi工具製作出Amazon的產品銷售網路圖，並對圖形的視覺化進行分析（圖5）。在圖中可以看到紅色到黃色節點代表著銷售收入的多到寡，節點大小則為銷售數量的多寡，而線段的粗細代表著購買此商品時連同購買其他商品的次數。在對此網路圖做分析後作者得到了一些有趣的結果，可以從節點的顏色及大小找到最暢銷的商品及最不暢銷的商品。另外也從線段連結的粗細找到相關性最強的商品，消費者在購買此一商品時通常也會購買另一項，並且再深入探究節點顏色及大小可以發現有些商品的暢銷同時也會使另一項商品的銷售有所成長。而在此視覺網路中分成許多區塊，作者分析出從最大區塊中連結最密的商品來挖掘出最具影響力商品，此商品帶動了許多商品的成長創造出最高的收益。

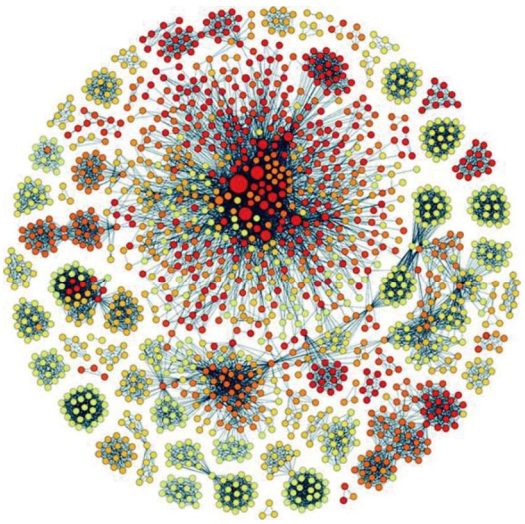

圖 5. 來自 SNAP Amazon 產品數據集繪製的產品銷售網路圖(Mithili Devi & Kasireddy, 2019)

上述圖表中作者以視覺化網路圖的呈現來進行分析，在(Mithili Devi & Kasireddy, 2019)文章中也從 Gephi 的統計數值上驗證了其圖表分析的準確性。然而，在過去研究中也有對學術網路圖有類似的分析，其利用視覺圖表對中心度、頻率、網路密度以及聚類模塊等來做找尋研究熱點與研究趨勢的相關分析(Weihua & Dong, 2021)。在上述這些案例中皆是使用工具呈現數據網路圖，再從網路圖中分析出重要節點、整體脈絡及發展趨勢。因此視覺圖的呈現不只是對於快速理解內容有幫助，而是能運用此圖表進行分析與研究，挖掘出數據中隱藏的資訊內容。

2.3 視覺化工具

資訊視覺化的工具有非常多種，也有許多研究人員及商業人士開發出許多資訊視覺化的工具，並以此方法來幫助判讀及解決的問題。而這些工具都是由許多方式來進行開發，目的也不相同甚至很多具有針對某些特定領域的數據資料，但其中也有較普遍性的視覺化工具，大致可分為需要編程的工具與不需要編程的工具。現今不需要編程的工具種類繁多，已經可以處理非常多視覺呈現，但其缺點就是沒辦法自由修改及調整，只能依照提供的套件來做使用，例如 Tableau、RAW Graphs 及 iCharts 等。而需要編程的視覺化工具，多數是使用 JavaScript 來製作互動型的視覺圖表，但有些過程中要結合其他語法像是 PHP、Python 或是 R 語言等，在（圖 6-1、6-2）中分為主要使用 JavaScript 以及使用其他語法的視覺化工具(Liu et al., 2018)。

Framework name	Input data format	Rendered charts by	Charts and maps type	License from
D3.js	JSON, CSV, and XML	HTML5 canvas, SVG and CSS	A powerful D3 gallery with multiple charts, graphs, and maps including the world map and the US map.	BSD-3
Chart.js	JavaScript API	Only HTML5 Canvas	8 chart types, including over 23 charts and graphs.	MIT LICENSE
FusionCharts	JSON, XML	SVG, VML	90+ charts and graphs, 1000+ maps including all continents, major countries, and all US states.	Free for basic edition and advanced commercial edition.
Flot Chart	JavaScript API	Only HTML5 Canvas	The charts of lines, points, filled areas, bars and any combinations of these charts. Doesn't support maps.	Free
ZingChart	JavaScript API	HTML5 Canvas, SVG, and VML	Plenty of chart and graph types in its ZingChart gallery. Support almost every country and area.	Free for basic edition and advanced commercial edition.

圖 6-1. 基於 JavaScript 的視覺化工具(Liu et al., 2018)

Tools	Input data format	Language-based	Features	License from
Gephi	CSV, Excel files,	Java, OpenGL	Powered by OpenGL engine. Force-based layout algorithms shape the graph.	GUN, GPL
Nodebox 3	CSV	Python and Clojure	Integrate all the functional parts in nodes.	GPL
Ggplot2	R, API	R	Plotting based on layers. Graphs composed of layers.	GUN, GPL, and V2
Processing	Multiples of formats are available in its library	Java, plugins for Python and JavaScript	Integrate the OpenGL engine. Over 100+ libraries offered to expand its usage.	GPL, LGPL
JpGraph	CSV, From databases such as mySQL	PHP	Tiny size of generating images. Anti-spam images is supported. 3D effects is also supported.	Free QPL, paid for commercial

圖 6-2. 基於其他語法的視覺化工具(Liu et al., 2018)

這些視覺化工具的使用範圍較廣，使用程式語言更是初始的操作形式，能夠自由操作且製作一套客製化系統，而其中 D3.js 與 Gephi 是目前許多資訊視覺化的使用首選。Gephi 是繪製資訊視覺網路圖的熱門工具，由 Mathieu Bastian 等人於 2009 年開放及發表。該工具可以顯示 875713 個節點與 5105039 條連結線，使用 3D 渲染引擎能夠即時顯示海量數據所製作的大型網路圖，快速的加載及運行是其重要的特性(Bastian, Heymann, & Jacomy, 2009)。Gephi 可以計算不同的中心性度量（中間度、接近度、偏心度）等數據分析計算，並提供查找各種計算函數的功能。該工具也提供不同佈局的圖表顯示，並且能夠從介面中更改外觀、大小及顏色，將每一筆數據進行分類，這有助於進行有效的視覺化操作並從過程中進行分析（圖 7）。此技術多被應用於探索性數據分析、鏈結分析、社交網路分析及生物網路分析，而此工具無需編程技術的操作方式也深受資訊視覺設計師的青睞，因此其十分適合用來製作大數據的網路視覺化圖表(Faysal & Arifuzzaman, 2018)。

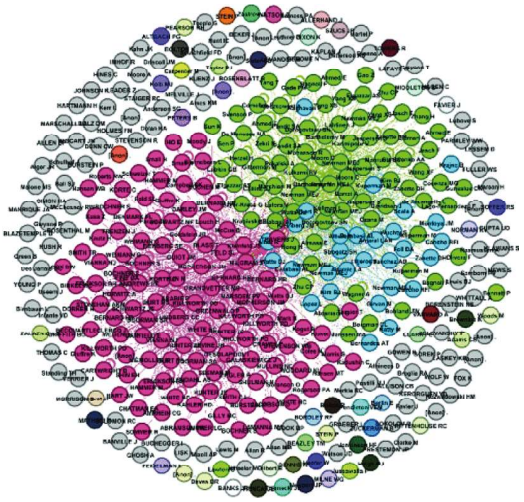

圖 7. 使用 Gephi 繪製的網路圖(Faysal & Arifuzzaman, 2018)

D3.js 是 JavaScript 圖形庫中的開源程式庫，由 Mike Bostock 等人引入的由 JavaScript 編寫非傳統視覺化框架，且為用戶提供許多示例及技術文件。其結合了 HTML 及 CSS 技術，視覺圖是由網頁來進行呈現，代表著能經由網路執行遠端的修改，視覺圖能隨著數據的更動而同步改變(Bostock, Ogievetsky, & Heer, 2011)。D3.js 的全名為 Data-Driven Documents，是一個使用動態圖形來顯示資料的 JavaScript 數據庫。它可以將數據加載到瀏覽器的內存空間中並綁定到 DOM (Document Object Model)上，通過使用 HTML、SVG 及 CSS 對數據進行操作，將 JSON、XML 等數據文檔轉換為視覺化圖形呈現。

D3.js 對 Web 瀏覽器有著高度兼容性，不需要而外在安裝外掛執行程序，只需要在 HTML 的<head>標籤中導入 D3.js 源文件即可，相比於 Echarts 等高度封裝的開源視覺化資料庫，有更高的靈活性與擴展性(Bao & Chen, 2014)。而在此研究中選擇了 D3.js 作為開發工具，第一點為與 Gephi 相比之下，可編程的視覺化工具能繪製更多種類的視覺圖型，且有較高的靈活度能夠依照需求繪製自訂化介面。第二點為 D3.js 使用 JavaScript 為基礎的方式，能夠在 HTML 中直接編寫而不需要另外安裝軟體，也能將資訊視覺圖以網頁方式呈現在網路之中，並且能夠隨時的進行修正與更新。D3.js 基礎的編寫方式，有助於開發一套完整的視覺化工具，並依照需求呈現出各種不同樣式的視覺化圖表。

2.4 小結

數據資料的視覺化能夠幫助讀取繁雜的資料，而在如今的大數據時代更是如此，資料就好比新石油是一個新的能源，資料能被解讀及使用，就可以幫助人們解決許多問題(Z. Wu et al., 2014)。而從上述的文獻探討中總結了三點如下：

(1) 將使用學術社交網路來觀察學者研究發展的拓展性分析，並以此方法來進行一系列視覺化的呈現與分析。

(2) 為了將龐大的數據簡化以便判讀，需要進行數據篩選及整理後匯入系統來繪製出視覺圖。然而，視覺化的呈現上有許多種表現形式，因此在文獻探討後找尋了最合適的圖表，選擇使用網路圖(Network Graph)來做為視覺圖的呈現方式。

(3) 在視覺化網路系統中將使用 D3.js 做為視覺化繪製的開發工具，以此來製作資訊視覺化圖形。

另外在 WOCAD 學術資料庫中記錄了許多研討會的數據，研究過程中將以資訊視覺化來發掘學術領域的發展脈絡及學者於學術領域的研究貢獻(Yao, Wei, Zeng, Fan, & Di, 2014)。目標能以學術社交網路圖來找到解答，同時也針對實驗的每個環節進行修正與評估，找到能夠表現目的的最佳視覺呈現方法。

3 資訊視覺化網路系統

根據上述的文獻探討，研究中將使用 WOCAD 學術資料庫來作為實驗基礎數據，此數據庫中存放大量計算機輔助建築設計領域的研討會及期刊資料。從中提取此學術資料並放至 MongoDB Database 來作為資料庫的存取系統，再使用 MEAN 套件來設計資料庫的介面，建立出有 CRUD(Create, Read, Update, Delete)的數據庫介面(Polo, Piattini, Ruiz, & de Calatrava, 2001)。此方式能使數據能同步從網頁中進行修改，再經由資料庫的讀取後立即呈現於資訊視覺化的網頁上，幫助設計者從前端來檢視後端的數據庫。而本視覺化呈現方法則以網頁型態架設，使用 D3.js 語法來作為開發工具，來建立學術社交網路圖並建立操作介面，來讓研究者能夠在視覺網路圖中檢視及調整呈現的資料與範圍。

3.1 系統設計

本研究為了建置一套視覺化網路系統，以能夠順利挖掘及整理數據後呈現視覺化。將主要使用者分為設計者與研究者，設計者負責整

理數據及繪製視覺圖，而研究者則分析視覺圖並從中挖掘學術發展與脈絡。在本實驗過程中，將資訊視覺化的系統設計分輸出端、運算端與輸出端過程如下（圖 8）：

(1) 輸入端：將 WOCAD 數據匯入到 MongoDB 資料管理系統，而設計者可從介面中來輸入及修改數據。

(2) 運算端（數據存取）：在 MEAN Stack 的系統中設計者從 Angular 提供的介面框架送出要求數據的請求，而 Angular 會向服務器要求數據存取，服務器中會由 Node.js 接到請求並隨即要求 Express.js 向 MongoDB 請求數據取得。
MongoDB 在接受要求後將數據傳遞給 Express.js，在 Express.js 收到數據後便會回覆給 Node.js，隨即 Node.js 再將數據傳給 Angular，在由 Angular 提供給研究者最終顯示結果。
此運算過程從兩個方向進行，由設計者從介面中進行操作來向數據庫要求數據資料，之後數據庫再將資料回傳到介面中。本階段主要為數據的檢視與調整，方便設計者在視覺化時能從前端來快速校正數據。

(3) 運算端(數據分析)：D3.js 匯入於 HTML 後，即可使用其程式庫來設計與繪製互動型視覺化圖表。MongoDB 將數據匯出成 JSON 格式後，D3.js 便可讀取數據內容繪製出節點與線段。CSS 可設定網頁的基礎字體與顏色等風格，而 HTML 則編排網頁框架並將全部內容呈現網頁中，因此研究者便可從網頁上看到視覺圖表的呈現以進行操作。
此階段主要為呈現視覺化圖表於網頁中，以 HTML/CSS/JS 的基本網頁架構進行建置，並與 MEAN Stack 共用 MongoDB 從而進行系統的結合。

(4) 輸出端：研究者可從網頁中觀看到視覺圖，設計者也可以介面中看到 MongoDB 的數據資料。在發現數據出現問題時，即可從 MEAN Stack 提供的介面對數據進行調整。過程中可由此方式來回的進行修正，讓研究者能更有效率的分析視覺圖。

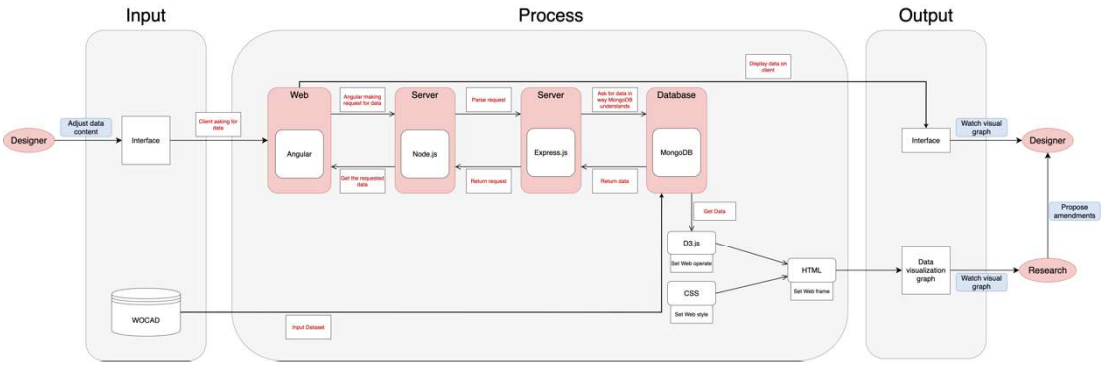

圖 8. 視覺化網路系統設計

從圖 8 中可以看到設計者會從 MEAN Stack 的介面中調整數據並將整理好的數據提供給 D3.js 取得後繪製出視覺圖，再進到網頁中呈現給研究者。然而，研究者在查看與分析視覺圖時需要修正數據或製作其他種類的視覺圖，因此可以將問題提供給設計者，再由設計者進到系統中進行修改。修正數據時設計者可以由 MEAN 進行快速的修正，而需要製作其他視覺圖時則必須從 D3.js 的代碼中進行修改。

此視覺化網路系統使用 MEAN 套件來建立資料庫系統的輸入/輸出端，以允許設計者將數據從自訂介面的網頁進行輸入、讀取、更新及刪除，有效的即時管理數據以及制訂介面。同時，在視覺化的頁面中也透過此方式來製作視覺化操作介面，幫助研究者在觀看視覺圖時能調整數據的呈現範圍與方式。

此系統主要著重在數據的快速提取以及將前端與後端的數據庫進行連結操作。為此，使用 Full Stack 的建置方式，來達到製作資訊視覺化時能夠從前端去做全部的資料控制。該方式讓設計者能夠在介面中有更多的自由度，並允許設計者在製作視覺圖時能夠進行即時的更改，不需要再進入到資料庫中調整數據的變量。

3.2 數據整理

本數據使用 WOCAD 的數據資料來做資訊視覺化，在此資料庫中取用了作者(Author)、著作(Work)、關鍵字(Keyword)三種分類的資料表，這三個資料表當中收集了許多相關數據，如（圖 9）。因此，需要將資料表的數據進行篩選及清理，後續才能做為視覺化網路的基礎數據。

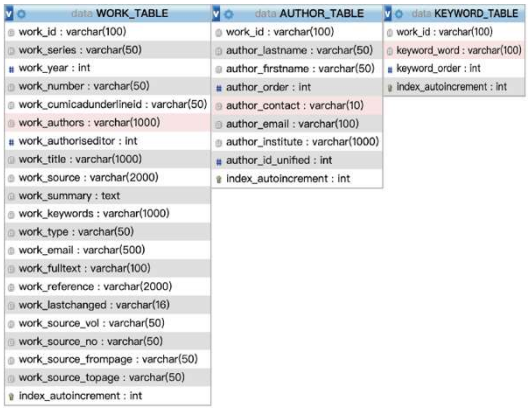

圖 9. WOCAD 數據庫資料表

WOCAD 的數據庫的原始資料是以 SQL 型態存放於以 Web-base 架構的 MySQL 資料庫管理工具(phpMyAdmin)，而在此之前需要將資料從之中提取出來匯入到 MongoDB 中。phpMyAdmin 能夠使用 SQL 語法來做資料查找，這使在做數據的提取過程中能做第一步的篩選動作。在資訊視覺化前必須將數據資料進行清理，取出有效且要被使用的資料來整理，避免在資料庫中數據過於雜亂影響匯出時產生錯誤。因此，確定視覺化的目標後立即針對要利用的數據進行整理與排列，而此一步驟在 MongoDB 這種 NOSQL 架構中更是需要注意，因為非關聯式數據庫容易在建立資料時產生過多訊息。首先，去除了有缺漏的數據資料表，以及不需要使用到的資訊，整理後的資料即匯入至 MongoDB，減少不必要的訊息存在於數據庫中（圖 10）。

圖 10. MongoDB 數據庫資料

圖 10 中可以看到在匯入 MongoDB 內的數據做了初步的篩選，並且與圖 9 的原始資料比較能發現過程中所去除的資料內容。在 Author 的資料表中只選擇了作者名字與作者發表的論文 ID，而 Work 資料表則是取用論文 ID、年份以及標題。進行此一步驟是為了只取得網路圖所需要的資訊，篩選掉輸入不完全以及不必要的資料，避免在資料讀取後產生出錯誤的視覺圖。

視覺化網路圖將根據這些資料來做不同的資訊視覺化呈現，從作者與著作相互關聯來找尋作者的研究貢獻，以及由關鍵字與著作關聯來查看學術領域的發展。因此研究過程的資料整理著重在這三個資料表，整理過後使用了作者名字、著作名稱以及關鍵字作為節點（圖 11）。過程中發現以大量的數據來做視覺圖時，節點的關聯配對無法以純文字來抓取數據，必須將其節點進行編號才能做出連結線段。因此，給予每個節點固定編號，來讓程式能根據編號來執行線段的繪製（圖 12）。

40	Amano Hiroshi	10	1
41	Amato Alex	10	1
42	Ambrose Michael	10	1
43	Ambrose Michael A.	10	1
44	Amindarbari Reza	10	1
45	Amir Oded	10	1
46	Amtsberg Felix	10	1
47	An Seyun	10	1
48	Anastasios Kotsiopoulos M.	10	1
49	Anay Hakan	10	1
50	Anbusivan R.	10	1

1980	113caadria2004	Case-Based Simulation As a Technique for Assisting Architectural Design	0.1	10
1981	114caadria2004	Situated Case-Based Reasoning As a Constructive Memory Model for Design Reasoning	0.1	10
1982	115caadria2004	Framework for Case-Based Reasoning to Support Idea Association in a Brainstorming Session	0.1	10
1983	201caadria2004	3D Transformations - 3D Scanning, Digital Modelling, Rapid Prototyping and Physical Depiction	0.1	10
1984	202caadria2004	Qualitative Shape Representation and Featurebased Comparison of Architectural Drawings	0.1	10
1985	203caadria2004	Space Adjacency Behavior in Space Planning	0.1	10
1986	204caadria2004	Design Knowledge Discovery in Cases - The Machine View Vs. the Human View	0.1	10
1987	205caadria2004	What Is Intention Structure? - Represent Invisible Information of Spatial Depicts	0.1	10
1988	206caadria2004	Diffusion of Design Ideas: Gatekeeping Effects	0.1	10
1989	207caadria2004	Computational Differentiation and Categorisation of Design Drawings	0.1	10
1990	208caadria2004	Discoveries Throughout Conceptual Design	0.1	10

圖 11. Node 的數據資料

109caadria2004	1976	Choi Hyun-Ah	305
109caadria2004	1976	Jun Han-Jong	747
110caadria2004	1977	Gero John S.	502
110caadria2004	1977	Peng Wei	1345
111caadria2004	1978	Biloria Nimish	113
112caadria2004	1979	Hsieh Chun Yu	632
113caadria2004	1980	Chen Hong-Sheng	235
114caadria2004	1981	Liew Pak-San	1025
114caadria2004	1981	Maher Mary Lou	1113
115caadria2004	1982	Lai Ih-Cheng	930
201caadria2004	1983	Kuan Steve K S	904
201caadria2004	1983	Li Weidong	1018
201caadria2004	1983	Schnabel Marc Aurel	1499

圖 12. Link 的數據資料

首先，由 MEAN Stack 的 MongoDB 資料庫匯出 Author, Work, Keyword 資料表內的相關數據，在 Author 表內分為 author_lastname 與 author_firstname。因此，彙整作者名稱為全名以避免在節點中出現不同人卻同名或同姓氏的狀況。接著，將作者(author_name)與著作(work_id)做節點的編號(node_id)，讓線段連結時能根據編號進行繪製。最後，由 D3.js 讀取資料並繪製出視覺圖來提供給研究者，而研究者在查看視覺圖後提出問題給設計者，在了解後可以進入到 MEAN 的介面對數據進行修正（圖 13）。

圖 13 中的左半部分為作者發表網路的數據流程圖，而右半部分則為關鍵字連結圖的數據流程圖。灰色數據為原始 WOCAD 的數據資料，而橘色數據則為在過程中產出的新數據。可以看到設計者從 MEAN Stack 中將數據匯入後，數據需要進行整理並設定為節點或線段，最後將整理好的 JSON 資料提供給 D3.js 抓取後便呈現出視覺圖給研究者做查看與分析。然而，資訊視覺化的分析過程中需要進行多面向的比較，因此研究者會將問題反饋給設計者，而設計者在根據問題從系統中重新調整數據並製作新的視覺圖給研究者，以此反覆的做滾動式設計與分析。

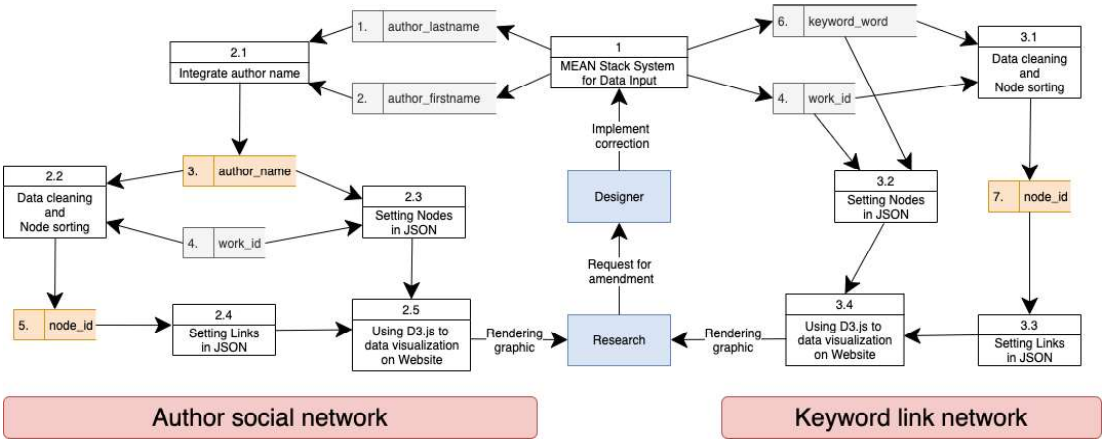

圖 13. 視覺化網路系統的 Data Flow Diagram

3.3 環境架設技術

本實驗中使用 MEAN Stack 的全端架構技術來將 MongoDB 的數據庫能系統化，讓其可以在網頁中調整及查詢數據庫功能。並以此系統來管理數據庫的資料，方便在進行視覺化時能即時查看並修改後台數據。第一步先架設好以 MongoDB 作為數據庫的系統環境，再將 WOCAD 數據匯入至此系統中。WOCAD 數據庫原本是存放至 SQL 系統中，因此原則上也可以使用 SQL 的環境，但在資料整理上會變得較為複雜，需要使用其他語法及系統來做數據調整，所以採用 MEAN 套件中的 MongoDB 來作為系統的數據庫使用。而進入到 MongoDB 的數據在之中每一筆都將會建立出一個 ID，這能方便在尋找每一筆被輸入的資料內容。

接著，使用 VS code (Visual Studio Code) 編寫 MEAN Stack，由 VS code 內建命令列工具來安裝 Node.js 幫助連結前後臺，並使用 Express.js 來建構後端 Web 架構與 Web 服務。另外，再以 Angular 來編寫前端框架，Node.js 則會在中間扮演環境的轉譯，讓整個環境中都能使用 JavaScript 進行程式撰寫。在架設完 MEAN 套件後，此系統可以由 Express.js 獲取 MongoDB 的數據，並呈現在由使用 Angular 框架建立的網頁中。在此網頁編輯的資料也會同時改變數據庫的內容，即架設出一個自定義的資料庫介面，以此來控制數據庫中的資料（圖 14）。

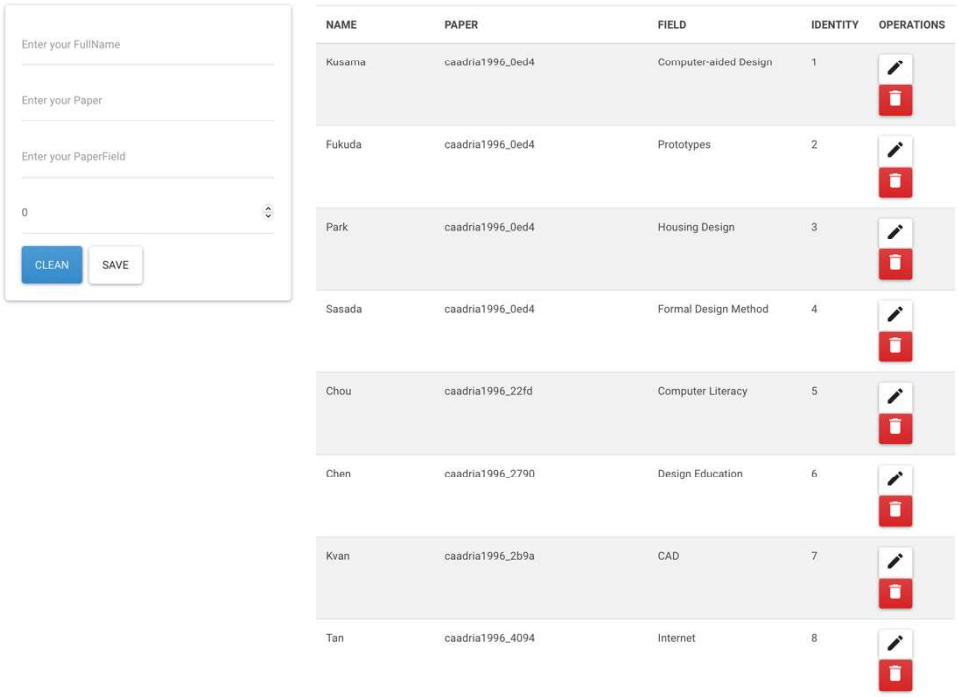

圖 14. MEAN 前端資料介面

藉由此介面能夠幫助管理數據庫的資料，以及管理資訊視覺化的數據形態。在不同的視覺化圖呈現時會有不同的資料項目需求，而研究者在進行資訊視覺化的分析時也需要進行多面向的比較。因此，使用 MEAN 套件能快速更新及增加資料，幫助設計者能夠即時更正錯誤的資料，並且快速的產生新的視覺圖以此讓研究者能從中進行研究與分析。

過去使用 D3.js 在操作資訊視覺化以產程視覺圖時，需要將後端資料進行篩選、清理、排序後匯出，接著再使用 JavaScript 去抓取匯出後的資料。如果要直接連結到資料庫讀取數據，則要寫 PHP 來轉換資料格式，且數據庫的資料也是要進入後端來做修改，造成在操作上的不便。而 MEAN 套件除了能夠在前端連結後端進行數據呈現以及修改外，其全由 JavaScript 的編寫形式，也讓製作時變得更容易去撰寫程式。

3.4 小結

本次研究的實驗方法重點在於建置出一套可用於學術視覺化呈現的網路系統工具，在 WOCAD 數據庫中含有數萬筆的資料，因此在資訊視覺化呈現時必須能夠負荷大量的資料處理。而本視覺化網路系統需要具有靈活性的介面操作，幫助學術研究人員在進行視覺化時，能夠根據數據的呈現進行更改與調整，這有助於在執行數據分析時的分組與比對。因此，在系統的設計上，使用了 MEAN 結合 D3.js 作為開發工具。D3.js 能夠直接的寫入在 HTML 的檔案中，使用現今熱門的網頁架構互動程式語言 JavaScript 做為基礎，在開發上能夠直接在網頁端即時呈現。而 MEAN Stack 環境也能讓後端的資料與前端網頁相互連結，幫助設計者在操作資訊視覺化工具時，能夠從前端網頁去調整後端的數據內容。另外，開發者在環境架構時，也因為皆使用 JavaScript 語法的特性，在維護及程式撰寫上也更為容易，降低了開發視覺化工具的門檻。

4 視覺化呈現及分析

此系統的視覺化圖形製作以 D3.js 為主要繪製工具，將 D3.js 匯入至 HTML 的文檔之中，以此來利用 D3.js 的程式庫。接著，將存放在 MongoDB 的數據資料鎖定並提取後，轉換成 JSON 的文檔提供給 D3.js 做讀取。最後，D3.js 會從數據文檔中將資料編列出的節點(nodes)及連結線段(links)繪製後呈現，以此產生視覺圖並呈現於網頁之中。

資訊視覺化圖表的呈現上以學術社交網路圖作為主要的應用，為了呈現出學術領域的研究發展脈絡以及作者於學術領域的研究貢獻，將以作者、關鍵字及著作關係進行連結，透過了關鍵字及著作關係來觀察其發展脈絡，再藉由作者及著作關係來觀察作者在該學術領域的研究貢獻。從 WOCAD 數據庫中提取大量的學術數據，以此呈現出整個研討會的學

術網路，再從每一個視覺圖中進行判讀及分析。在環境架設上因為使用 MEAN Stack 套件作為系統介面，因此在做數據調整時能更加方便的執行操作。將程式編碼寫入文字編輯器後，即可從網頁中操作視覺化圖形，因此在開發工具的使用上主要是以 MEAN Stack 結合 D3.js 作為系統的基礎架構，來進行視覺化圖形的製作。

4.1 作者發表網路圖

首先，設計者必須從資料庫中搜尋需要的資料，使用 Mongoexport 來鎖定及匯出所需的資料，接著輸出成 JSON 檔後由 D3.js 來抓取資料，最後會由 D3.js 所編寫的 JavaScript 腳本內容呈現出視覺化的圖表。在搜索數據過程中 MongoDB 的資料會由其語法作為鎖定，語法類似於 SQL 的語法結構，由此進行篩選及檢視資料，以此方式來彙整節點與連結線段的資料內容。呈現的視覺圖會由資料內容來顯示各節點的名稱，在 Author 的資料中節點名稱為作者名字，而 Work 的節點則為論文編號。

接著，從 WOCAD 數據庫中抓取 1996-2015 年 CADDRIA 研討會中以作者與著作連結的共同作者網路，每一個節點中為作者、共同作者與各年發表著作，分別以不同的顏色表示類別，作者為藍色節點而著作分別以不同顏色來表示不同年份的著作以方便判別與查看。連結線段則以著作與作者做連線，以作者節點來連結到其著作節點，如此相互連結後即可呈現出許多緊密相連的區塊（圖 15）。在圖 15 中，能看到作者所發表的著作與共同作者，彼此間的相互連結會呈現出一塊塊的連結區塊，而這些連結會將作者間發表的關係表現出來，可以讓研究者從中了解作者的相互關係以及發展脈絡。

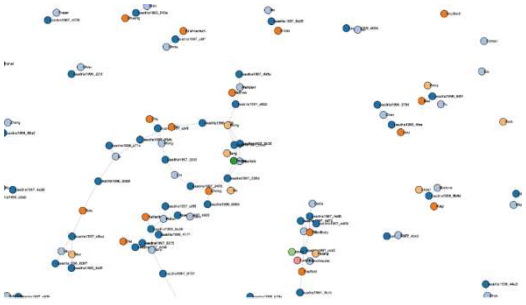

圖 15. 作者的發表著作網路圖

在此圖 15 的視覺圖中也發現了大量的顏色與訊息將容易模糊了視覺化的焦點，作者及著作的兩個節點同時出現於畫面中，造成解讀上容易混淆，另外，顏色過多造成研究者在觀看時無法判斷作者之間的相互連結關係，使得難以理解並分析作者的學術貢獻。因此，藉著此圖改變節點的資料來進行修正，去除著作的節點後只顯示出作者的節點，並以單一色（淺綠色）節點來表示作者節點，將重點全部聚焦在作者身上。這樣的方式能夠更清楚的表現作者之間的相互關聯，不會因為節點及顏色過多導致訊息上的混淆，並且在圖中以紅色、橘色及綠色來標示出重要作者。

在圖 16 所呈現出的作者發表網路圖中可以發現在只顯示作者時，能看到中間密集的區域為重要作者，從連結線段的密集度來看到重要作者的區塊從中尋找研討會中重要的作者發表網路。而外圍的小區塊代表著對此研討會較不深入的作者，但這些作者在研討會中的參與也同樣具有貢獻，但相比於中間密集連結的作者，在學術的堆積及延伸上就無對 CAADRIA 研討會如此深的影響。另外，在下面的視覺圖中可以看到紅色的圈選區塊為連結次數較多的作者區塊，在當中可以看到中心作者周圍的線段明顯較密集，可以從這些作者連結區塊能夠找到在研討會中較為重要核心人物。而紅色圈外的作者區塊較為零散，代表其在此研討會中較不深入，且在此學術領域的貢獻較少，因此可以藉由此視覺圖進行作者學術領域深入的判斷及分析（圖 16）。

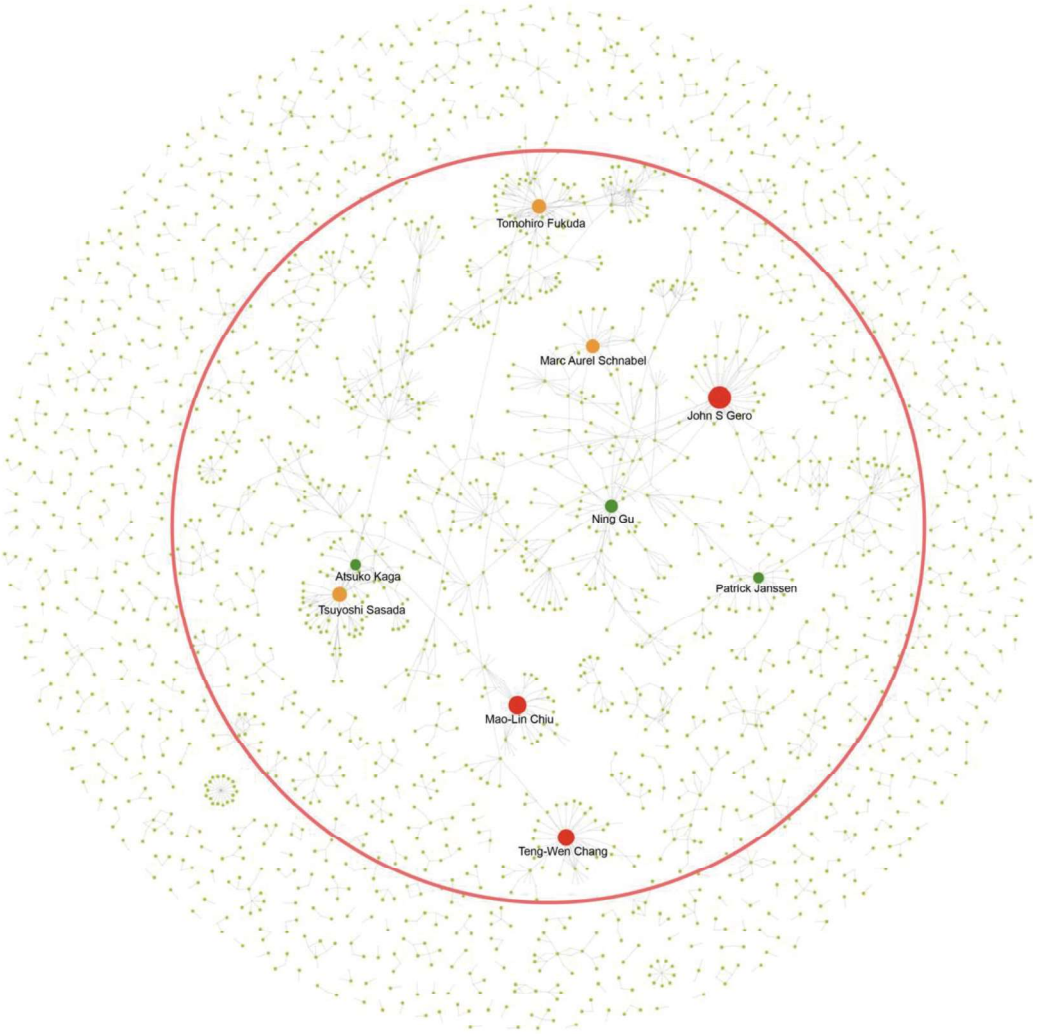

圖 16. 1996-2015 年作者發表網路圖

在此一視覺圖中，發現了該方式建立的共同作者網路，能看到學者在此研討會夠不夠深入，以及對研討會的深入程度。如果其作者節點只連結到幾個其他的作者節點，代表有可能是較少參與此研討會，且較少與他人合作。而作者與越多其他節點連結，呈現出較大的區塊連結，則代表其參與的程度較高，連結到的節點也同樣持續擴展呈現出一個鏈結區塊，可以判斷其中的學者研究方向是類似的。而外圍有許多零星的節點與區塊，可以看到多數為參與一次後就沒再進行合作，這些區塊也沒有與中間的核心有過任何的交流，因此成為了外圍的小區塊。在外圍的區域中對研討會的參與度較低，且合作的次數也較少，因此從此資訊視覺圖中可以看到此學術圈的人員在研討會的位置。在核心的學者對於研討會的貢獻較大，能夠對此學術進行更多的知識堆疊。而外圍學術研究者所提出的研究內容或許非研討會的重點研究項目，然而這點需要由更多的數據及資訊內容才能做為分析及判斷。

4.2 關鍵字連結網路圖

從上述的共同作者發表網路圖中可以找到研討會的重要作者，來尋找作者在學術研究的學術貢獻。然而，在學術領域中跨領域的合作是近年來重要的趨勢，不同領域相互合作所創造出的學術價值，能夠突破研究的發展來激發出更多的可能。因此，本次實驗以關鍵字來作為著作的學術方向，製作出一個關鍵字的連接網路圖。首先，取出 CAADRIA2008 年資料來做一個 Arc Diagram 的資訊視覺圖表，可以看到此表示依據連結線段的次數來做排列，由右到左依序遞減連結頻率，而左側深藍色的節點為研討會的著作文章，右側淺藍色的節點則為所使用的關鍵字。而越靠左邊的淺藍色節點則可以視為當年最熱門的研究項目，因此在視覺圖中研究者可以找到每一年的重點研究主題（圖 18）。然而，單一年的數據對於判斷研討會的研究趨勢太過薄弱，且這樣難以看出關鍵字的使用在每一年的變化。因此，需要逐年

的視覺圖來進行分析，接著再使用上述共同作者發表網路圖的方式做出整個 CAADRIA 的關鍵字連結圖，來看此視覺圖是否能表現出改研討會重點的研究項目。

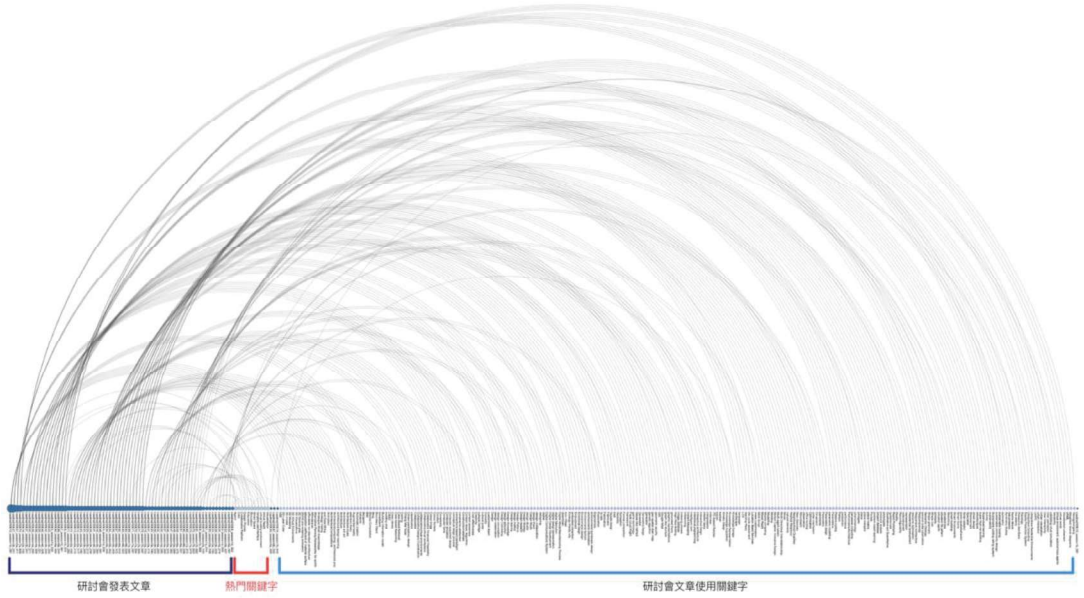

圖 18. CAADRIA 研討會 2008 年間關鍵字 Arc Diagram

接著，再以作者發表網路圖的呈現方式，再建立一個以關鍵字為主的視覺網路圖，來觀察研討會中關鍵字的關聯性。在 Arc Diagram 的視覺圖中因其以橫向進行排列，無法在圖表上呈現過多的數據。因此，以 Network Graph 的方式再呈現一個視覺化網路圖，從中來進行觀察與比對。而領域別在此研討會的數據蒐集中並沒有特別進行分類，因此使用關鍵字來作為其文章的研究領域。每一篇文章中都包含了 3 至 5 個關鍵字，而關鍵字的建立也都根據了文章的內容做出相符的設定，大致代表了文章中的研究方向。所以關鍵字在研討會文章中也一定的程度代表了其研究的領域類別，可以當作學術研究領域的依據，因此以關鍵字來作為其著作的研究領域。

在現今跨領域的合作已成為常態，單一領域的研究範圍也會隨著時代而與時俱進，因此在學術研究中時常包含著許多的領域結合。跨領域研究能夠幫助研究者在解決現階段問題時能有更多的思路，也能突破現有的技術框架，創造出新的研究領域，以此來對領域做延伸發展。因此在學術發展中研究領域的變化是十分重要的因素，代表著該領域在學術研究中的延伸性及拓展性，從此之中也可以挖掘出研究領域的深入程度。而製作此視覺圖的目的，是為了在資訊視覺化過程中能夠挖掘到研究領域的發展脈絡。而發掘重要的研究領域，能夠幫助研究者在之中找到可以發展的項目，也讓學術圈的學者從此視覺圖中看到此領域是如何做發展，並找尋未來可以如何做跨領域研究。同時也觀察學術圈其他人員是如何發展出一套自己的學術領域，也能夠以此圖做為分析，來判斷學術文章對於學術圈的貢獻程度。在關鍵字網路圖的視覺化圖形製作中，使用大量的關鍵字資料，每一位作者關鍵字使用上也會略有不同。因此在製作視覺圖前做了初步的篩選，將同義的關鍵字做出相同命名，避免產生相同的節點重複出現的問題。

在此視覺圖中可以看到與共同作者網路圖的圖形相似之處。中間區域的連結十分密集區域為此研討會的熱門關鍵字，其與研究領域有著密不可分的關聯性，因此可以判斷這些節點為此研討會重要的研究項目。以淺綠色節點來標示關鍵字名稱並連結其關鍵字所被使用的著作，來呈現出能夠找尋重要研究項目的關鍵字連結網路圖（圖 19）。

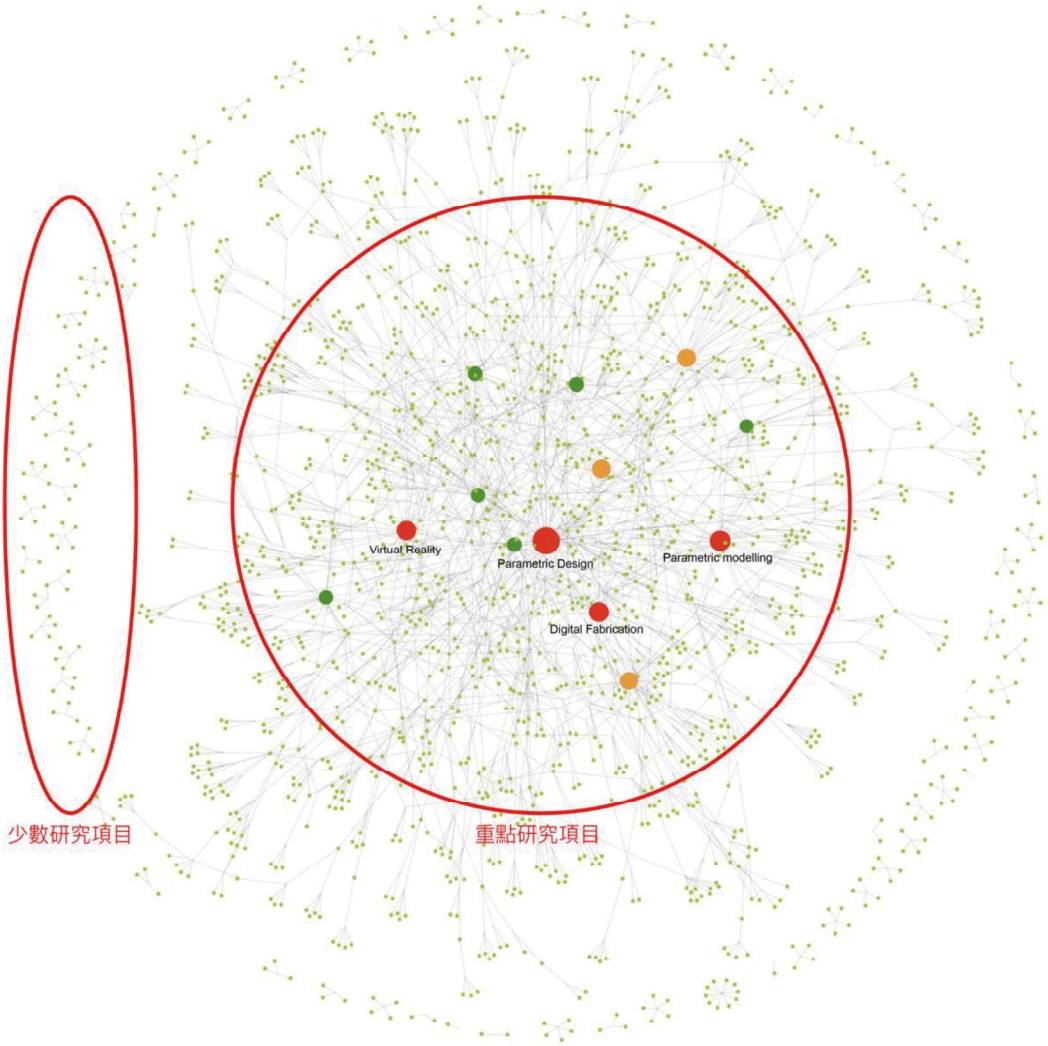

圖 19. CAADRIA 研討會 1999-2015 年間關鍵字連結圖

在這個研討會關鍵字連結圖中，可以看到中間密集的區塊代表著 CAADRIA 的重點研究項目，也可以將這些關鍵字視為在研討會中挖掘最深的研究領域。可以由此圖觀察到此學術領域的發展脈絡，從重點研究項目中來探討此研討會在該領域之中著重的項目。每一年的學術研討會都是對該領域進行學術堆積，而時常被使用及討論的關鍵字將會使此研討會對該領域有更深的見解。因此本視覺圖能夠使學術研究者發掘該研討會主要的研究項目，以及其他跨領域的研究趨勢。

4.3 重要作者發表網路圖分析

在上述的作者發表網路圖及關鍵字連結網圖中，可以看到使用此視覺化網路系統能夠將 WOCAD 數據庫中 CAADRIA 研討會的數據資料全部呈現在視覺圖之中，並且以線段連結將數據間的相互關聯連接在一起。這樣的視覺圖能夠幫助參與 CAADRIA 的學術研究者觀察研討會的學術發展以及自身在研討會的學術累積成果。在圖 18 中可以看到中間的區塊顯示出發表較多的重要作者，從中了解知識的傳遞與擴展方向。而圖 20 中顯示出研討會著重的研究項目，看到研究領域發展及學術延伸。這讓學術研究者在進入研討會時，能夠根據此視覺化網路系統製作的視覺圖來了解自身在研討會中的自身位置及貢獻，以及從關鍵字中探索及制訂未來在研討會中的研究方向。

在作者發表網路圖中作者可以看到整個研討會發展以來的重要作者及每位作者在此學術網的位置，然而，在 CAADRIA 研討會 20 年間的發展過程中會經歷許多變化。學術網在不同時期都將有重要作者的轉變與知識的傳承，因此接著再分析前十年及後十年的作者發表網路圖，並將前十年與整個二十年的圖表進行三張網路圖的比較分析。

首先，以作者發表網路圖方式製作了 1996 到 2005 以及 2006 到 2015 的視覺網路圖，將整個研討會的時間線由中間切開製成兩張圖表，並且為了避免圖表內的內容過於雜亂以方便後續的分析，將學術網中低於 10 個節點的發表網路鏈結區塊刪除，把分析聚焦在重要作者發表網路的發展變化（圖 20）。

在圖 20 中可以看到左邊為前十年，而右邊為後十年的重要作者發表網路圖，在兩張視覺圖裡個別取九位重要作者。重要作者依照發表篇數決定節點的大小，而節點顏色也依據篇數切分成三個等級，由多至少排列為紅色、橘色及深綠色節點且圖中只標示出重要作者的節點名稱。

圖 20. 左圖為 1996-2005 年重要作者發表網路圖；右圖為 2006-2015 年重要作者發表網路圖

從圖 20 的重要作者發表網路圖中可以發現 1996-2005 年間與 2006-2015 年間的重要作者有了很大的變化，在 1996-2005 年網路圖的重要作者(紅色節點)為 CAADRIA 聯合創始人 Tsuyoshi Sasada 以及 CAADRIA 院士 John S Gero 與 Mao-Lin Chiu，而主要以 Tsuyoshi Sasada 建立的鏈結區塊最為密集。然而，2006-2015 年網路圖的重要作者轉變為近年較為活躍的兩位院士 Tomohiro Fukuda、Marc Aurel Schnabel 以及 Ning Gu 教授，並且發表網路的鏈結區塊變更為密集且龐大。從這兩張視覺圖的比較分析中可以探索出兩個結果：

(1) 作者合作發表逐漸頻繁：在前十年研討會的發展中學術合作尚未建立完整，主要是以重要創始人 Tsuyoshi Sasada 發展出密集的共同發表鏈結區塊。然而，在後十年的重要作者發表網路圖中重要作者之間有了更多緊密的合作，學術網的結構也變得更為密集且龐大。

(2) 作者在研討會的學術發展：在兩張視覺圖的比對中可以看到 CAADRIA 院士 John S Gero 在後十年的發展雖然從紅色節點轉變為橘色節點，但是其發表網路鏈結區塊卻發展的最為龐大，並且在此區塊當中還產生了五位重要作者。另外也發現 Teng-Wen Chang 教授在過程中逐漸發展其發表網路鏈結區塊並從綠色節點轉為橘色節點，而 Mao-Lin Chiu 教授則發展得較為緩慢從紅色節點轉為綠色節點。因此研究者可以在此視覺圖看到研討會中作者的發表變化，從中找到近年發展較為快速的重要作者。

在圖 20 中可以分析出前十年與後十年作者在研討會中的不同時期的發展變化，然而還需將此與整個二十年間的網路圖進行時間線比較，才能觀察並分析出整體的發展脈絡與變化。接著，再將前十年與整個二十年研討會發展的重要作者發表網路圖進行比較，以挖掘研討會在發展中重要作者與發表網路的鏈結區塊的變化。同樣為了更好的進行分析將較少的區塊去除，只保留了較大的鏈結區塊以方便做重要作者的比較分析。另外也增加了九位重要作者以黃色節點與較小的字體顯示作者名稱作為標示，並且其發表篇數少於綠色節點的作者，因此節點顏色的排序由多至少分別為紅色、橘色、綠色以及黃色，並同樣依照發表篇數做節點大小的變化（圖 21）。

圖 21. 左圖為 1996-2005 年重要作者發表網路圖；右圖為 1996-2015 年重要作者發表網路圖

在圖 21 中可以看到紅色節點的重要作者有兩個相同分別為 CAADRIA 院士 John S Gero 與 Mao-Lin Chiu，這表示在此二十年間兩人仍不斷地在此進行發表，並在此研討會中有著卓越的貢獻。透過右邊的網路圖可以發現 John S Gero 在研討會中與院士 Marc Aurel Schnabel 以及 Ning Gu 教授建立出了最為龐大的鏈結區塊，且此區塊的作者頻繁與其他作者做共同合作發表，從中發展出一個緊密的學術網路，此外 Teng-Wen Chang 教授從綠色節點轉變為紅色節點並與其鏈結區塊開始有所接觸。因此，透過這兩張圖的比較過程中可以挖掘出兩個結果：

(1) 作者間的發展相輔相成：在圖 21 的比較中發現 Teng-Wen Chang 教授從綠色轉變為紅色節點的過程中 Ih-Cheng Lai 副教授也發展為黃色節點。而創始人 Tsuyoshi Sasada 從紅色轉為橘色時與其相關的日本研究者 Atsuko Kaga、Mitsuo Morozumi、Riken Homma、Kazuhisa Iki 四人也同樣變為為黃色節點，從中可以看出作者在發展的同時也會影響著緊密連結的其他作者。

(2) 研討會中的發表學派類型：重要作者發表網路中雖然已呈現出作者有更多的合作使鏈結區塊更加龐大且密集，但是在圖 21 右圖中仍然可以看到以重要作者 (John S Gero、Mao-Lin Chiu、Teng-Wen Chang、T. Sasada 及 Tomohiro Fukuda)為中心發展出的個別鏈結區塊。在中間的大區塊中許多鏈結區塊雖逐漸相互融合，但不難看出當中還是以重要作者為中心產生個別的密集範圍。因此研究者可以根據此圖來探究個別區塊的研究類型與學派，並且以此來挖掘在領域中學派的發展與變化。

4.4 小結

在上述研究過程中可以發現，此視覺圖能夠幫助研究者對研討會有更深的理解，並可以藉此找到重點的作者及研究項目，而作者發表網路圖的比較分析甚至可以幫助研究者挖掘出作者對研討會的影響及更深的發展脈絡。在學術資料的視覺化呈現操作時需要先制定明確的目的，取得有效且可利用的數據再以此資料進行資訊視覺化。然而，資訊視覺化所呈現的視覺圖還需要再進行數據分析，才能得到有用且具有價值的資訊。有效的視覺圖能幫助研究者在觀察數據能更快看出其中的資訊，而經過分析網路圖的內容可以從中獲得更多訊息，讓研究者根據此來制訂未來在 CAADRIA 研討會的研究方向。

本研究建置的資訊視覺化網路系統，能夠快速的從數據庫中提取資料並呈現大量數據的網路圖。另外，在分析了使用者(設計者、

研究者）運用系統操作視覺化的過程中，可以從中得到幾個結果：(1)設計者可以使用此視覺化網路系統快速的製作視覺圖，但資訊視覺化過程中卻需要不停修正圖表來進行迭代，因此設計者能操作系統並在分析過程中根據研究者的需求來進行調整。(2)此系統能匯入大量數據來做視覺圖，因此研究者在進行學術的脈絡挖掘時，能夠從整個研討會或學術圈來觀看，並從關聯性中找到作者的發展脈絡與學術發展趨勢。(3)此系統使用的 D3.js 具有非常高的自由度，因此設計者能夠從中繪製出各種不同類型的視覺圖，這可以幫助研究者在過程中能使用不同的圖表來進行比較與分析。

5 討論

根據以上資訊視覺化實驗，可以看到本系統能夠建立輸入及編輯的操作介面，並且根據數據資料而改變視覺圖，這能幫助在製作視覺化分析時能快速地修正資料。在研究中已經做到自訂控制數據的前端網頁，讓資料能被輸入及管理，而使用 D3.js 所編寫的程序能抓到 MongoDB 所匯出的資料，並從此數據來繪製出視覺圖，減少了數據在匯出後整理及轉譯上的步驟，讓資訊視覺化能更有效的進行。而 MEAN 套件中皆使用 JavaScript 來編輯方便跨平台的格式統合，降低了程序撰寫上的門檻也更為方便來管理程式及系統維護，能幫助設計者有效的進行數據清理與篩選。

在第 4 章中，為了呈現出作者於學術領域的研究貢獻及學術領域的發展脈絡，分別以作者、關鍵字及著作關係來進行資訊視覺化，產生出作者發表網路圖及關鍵字連結網路圖。然而，針對兩種視覺圖的呈現上還需要進行近一步的分析與探討，因此在 4.3 中我們以作者發表網路圖進行比較分析，製作出 1996-2005 年、2006-2015 年作者發表網路圖並與整個二十年的網路圖做相互的比較與分析，從中來了解 CAADRIA 研討會中作者發表的脈絡與學術發展趨勢。本資訊視覺化系統可以有效協助做出多種網路圖並以此進行比較分析，且此系統可以連結前後端並使用大量數據快速進行視覺化，讓研究者能夠透過此系統來快速搜尋脈絡並即時分析，而設計者能從前端進行資訊視覺化設計快速的產生視覺圖。在研究中也測試了許多種類的視覺圖效果並從中進行分析與研究，然而資訊視覺化的過程是滾動式更新，需要不斷進行資料搜集、分析、視覺化，來回的進行迭代才能尋找到最適合的視覺圖，並從圖中察覺出當中重要的訊息與有價值的內容。因此，在過程中也嘗試使用不同的數據來進行解讀與比較分析，而同時也發現在研究者理解數據時需要使用更多功能來操作視覺圖的呈現，才能將數據進行分組、關聯排序及交叉比對。

6 結論

本次研究成果所建立出的資訊視覺化系統能夠幫助研究者進行視覺圖的探索與分析，從圖中快速理解大量的學術資訊並以此進行分類與比較，另外也讓設計能從系統中能依照需求製作不同種類與數據形態的視覺圖，可以方便管理數據並做出即時的視覺化呈現。因此，研究者能在視覺圖中分析研討會中作者及領域的發展脈絡，並且從中挖掘數據難以察覺的內容，幫助研究者在決策後續研究的合作及發展方向。

在研究過程中我們從共同作者發表網路圖看到了作者間的相互關係，並找到每位作者在研討會中的所處位置與深入範圍，在關鍵字連結圖則可以查看研討會的學術領域發展分佈，從中找尋重點研究領域。最後，將分年作者發表網路圖進行比較性的視覺化分析，從各時間段的網路圖中看到作者在研討會的發表變化，挖掘到重要作者的轉變以及分析作者在研討會中是逐漸發展或衰退，而同時也從中發現了同一區塊鏈結的作者間發展是相輔相成的。在尚未建立出累年的數據視覺圖時，難以看出整個研討會的研究發展狀況，而在不同視覺圖中就可以看到整個研討會的學術脈絡及發展，並能從中進行更深入的分析與研究。

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原著英雄造形創作之研究-以孫悟空為例

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摘要

《西遊記》不僅是家喻戶曉的奇幻小說，也是許多台灣與中國大陸的電腦動畫、漫畫及遊戲產品的重要取材。該書作者吳承恩才華洋溢卻身處腐敗的官場文化而有志難伸，出自他手筆的孫悟空即代表在明末清初的封建社會，敢於挑戰神或一般平民碰不得的惡勢力當權者，勇敢又忠誠的英雄。本研究的主題是《西遊記》一書的孫悟空，藉由文獻探討以比較孫悟空在近代動漫市場上的造形形象演變，分析不同時期的形象特色。從而梳理出近十年孫悟空造形題材在國內市場停滯不前的原因，並深掘原著《西遊記》百回本孫悟空原始造形設定，透過平面繪製與 3D 軟體的交互使用，呈現吳承恩所描述最原始樣貌的孫悟空妖猴造形，再針對世界市場未來的展望，將之打造成能融入未來世界市場的新造形，本研究所創造的孫悟空，期待提供一個可供未來類似題材參考的設計樣板，未來運用於《西遊記》題材的相關商業創作時，可以結合在古裝的《西遊記》相關的電影或動畫、遊戲，也可融入現代的英雄舞台，貼近本世紀忙碌卻心靈空泛的觀眾心中。

關鍵詞：西遊記、文化形象、創新、超級英雄、孫悟空。

A Study on the Creation of Heroes in the Original Works-Taking Monkey King as an Example

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ABSTRACT

"Journey to the West" is a well-known fantasy novel and inspired many computer animations, manga, and game products in Taiwan and Mainland China. The talented author, Wu Chengen couldn't bring his ideal into full play because he lived in the age when the Chinese government was corrupt. The Monkey King from his hand represents the feudal society in the late Ming and early Qing Dynasty, challenging the evil powers of the gods or ordinary civilians. This research focuses on the Monkey King from the book "Journey to the West ." The literature compares the evolution of Monkey King's design in the modern animation market and analyzes the lack of elements in different periods. To sort out why Monkey King's modeling theme has stagnated in the domestic market, it creates the modeling conditions that Monkey King must have as a superhero. The Monkey King shape created by this research is equivalent to the "Baolian Lantern" version in 1999. The appearance has become more friendly and accessible with the completion of the scriptures. Faced with the ever-changing global market, this created the superhero Monkey King looks forward to providing a design model to reference the same theme in the future. When the superhero Monkey King uses the commercial creation of the theme of "Journey to the West" in the future, it combines with the "Journey to the West" related movies, animations, games or incorporating into modern stage plays; it is close to the hearts of the busy but empty-hearted audiences of this century.

***Keywords*:** Character Modeling, Cultural Image, Innovation, Superhero, Monkey King

1 前言

中國的神話題材動漫畫發展已經超過 80 年的歷史，觀眾的審美訴求被西方動畫影響，出現了劇烈的變化，從領先多國到發展漸緩直至停滯不前，大眾審美文化影響了動畫角色的塑造，本創作將從西遊記角色之一孫悟空的造形為研究目標，藉由文獻探討以理出西遊題材的東方神話英雄原始的造形樣貌，跳脫真善美的完美設計思維，重新打造成適合未來趨勢的樣板造形，為未來西遊題材的相關商業創作在面對市場全球化時可提供一個可供參考的設計樣板。

1.1 研究背景

根據 Boxofficemojo 票房查詢網站顯示，2015 年由北京聚合影聯所發行的動畫電影片《大聖歸來》創下 1.5 億美金的票房，孫悟空武藝高強又機智勇敢、平易近人又帶來溫暖的本質，堪稱代表東方神話的超級英雄，2019 年漫威影業聯合旗下眾多超級英雄集結成的復仇者聯盟系列電影 Avengers: Endgame（2019），創下全球票房 27.9 億美元的驚人成績，再次刷新全球賣座電影榜首。與西方的超級英雄比較之下，孫悟空的能力與資歷是毫不遜色的，在國際市場對孫悟空的認識卻依舊是段落與片面，孫悟空的戲劇自明朝開始不停傳頌到今天歷時四百多年，推出相關的影片戲劇不下兩百部，要想走上世界舞台，除了文化代表性，本創作研究試圖將孫悟空的造形再打造，以走向國際舞台為目標。

1.2 研究動機

自古以來，戲曲與評書都是傳承民間故事的重要管道，畢竟不論識不識字的人都愛聽動人的故事，加上戲曲與評書有音樂與視覺的刺激，更能生動地傳達故事的有趣性，在不是每個人都識字的那個時代，中國的絕大多數傳世經典著作也是透過這個管道，被戲曲以書籍文字的另一個完整的形式保存並流傳下來，所以說有很多著名的民間故事是被演過來的說法並不為過，孫悟空這個角色亦完整的保存在其中，在影視媒體普及的近代，他就穿戴著一身京劇戲曲的裝扮，成為東方神話的代言人活躍在每個影音媒體當中，他所散發的東方文化元素，被現代國內外的學術與商品大量的挖掘引用，這些文化元素的強大能量，不停地往全世界的每個角落散發，不斷的在影響著每個創作者。

近十年電影特效的突飛猛進，促使世界各國的神魔題材與超級英雄題材影片與遊戲動畫大量推出，快速的攻占世上每個人的眼睛，古老的文化元素不斷的被推陳出新的影片重新詮釋再詮釋，正義與邪惡的兩派角色身上的裝扮形象與裝備素質不斷的提升，創造一次又一次不平凡的票房與收益的奇蹟，尤其以近幾年推出的超級英雄電影最受矚目。本研究將整合歷史文獻探討對於當前的孫悟空造形的設計建議，輔以指定的研究方法，重新回歸西遊原著對於孫悟空的角色造形設定文獻，重新設計，使曾經是東方神話體系代表的孫悟空，還原成符合原著的設計原貌，並將孫悟空原始造形重新包裝，為未來國際舞台作準備，帶著通天本領與七十二番膽魄走向世界。

1.3 研究目的

本研究有三個目的：

（1）探討出國內神話題材動畫市場停滯不前的原因與突破現今困境的建議。

（2）依據西遊記原著對於孫悟空的原始設定，輔以指定的研究方法創作出最原始孫悟空妖猴造形。

（3）將孫悟空原始造形再打造，為世界市場的未來脈動作準備，為未來的造形設計提供一個造形藍本。

1.4 研究方法

依據 Lupton （2011）所提出的諸多方法中，強迫連結法 （Forced Connections） 與重新建構法 （Reconstruction） 交互使用，從平面繪製到 3D 軟體作交叉輔助，按照西遊記原著的描述，將原著孫悟空的角色原始造形呈現出來，亦可加入現代化美感的因素，呈現出西方風格的美感。

1.5 研究限制與範圍

本創作研究依據明·吳承恩《西遊記》為藍本作題材創作，研究限制範圍的說明如下：

《西遊記》僅以吳承恩著作的百回本《西遊記》小說為範圍依據，不納入其他版本作參考，以孫悟空的原著設定初始造形為主要設計骨幹，布衣僅納入平面設定範圍，3D 塑模以武裝為主。

2 文獻探討

本章就國內外學者對於西遊記的相關期刊研究文獻資料，探討與彙整，如：近代動漫畫電影裡面關於孫悟空的造形演變、原著裡面孫悟空的描述設定、孫悟空形象在世界舞台的發展狀況等做簡要說明。

2.1 組成孫悟空造形的三個維度條件

焦垣生、張蓉（2004）認為西遊記中的集物性、神性與人性於一身的神魔妖怪，就像三國演義裡的帝國將相與水滸傳裡的英雄豪傑，都是叱咤風雲的英雄，周先慎（2006）西遊記裡在孫悟空的形象塑造上最為鮮明的特性，即是神性、人性和自然性三者結合起來，趙青風（2014）孫悟空可稱得上是人、神、物的“合體”。因此，歷代大家與宗師們採用了各種不同的表演手法即是為了表現“猴子似人、神猴學人”的藝術效果，未來孫悟空的造形的設計這三個因素亦可以用作依據。

2.2 西遊記中孫悟空的角色描述與設定

孫悟空的族類在明·吳承恩《西遊記》百回本的第五十八回，雷音寺內如來世尊說明孫悟空的族類不屬於五仙與五蟲這十類之種，是獨特的混世四猴，有靈明石猴、赤尻馬猴、通臂猿猴、六耳獼猴等四種，其中靈明石猴就是指孫悟空。另外在西遊記更原始的版本大唐三藏取經詩話（宋人文本，2011）第二章《行程遇猴行者處》記載，白衣秀才形象的孫行者自我介紹時自稱「*八萬四千銅頭鐵額獼猴王*」。因混世四猴沒有任何生物資料可以參照，本研究創作以獼猴做為孫悟空的族類參考。

孫悟空的整體外貌描述在明·吳承恩《西遊記》百回本的第四回：「*一雙怪眼似明星，兩耳過肩眉又硬。挺挺身才變化多，聲音響亮如鐘磬。*」（明・吳承恩，1991，頁 47）。

第三十六回章節內對孫悟空原始相貌的描述：「*真個生得醜陋：七高八低孤拐臉，兩隻黃眼睛，一個磕額頭；獠牙往外生，就像屬螃蟹的，肉在裏面，骨在外面。*」（明・吳承恩，1991，頁 461；高桂惠，2021，）。

第五十八回章節內形容：「*模樣與大聖無異：也是黃髮金箍，金睛火眼；身穿也是錦布直裰，腰繫虎皮裙；手中也拿一條兒金箍鐵棒，足下也踏一雙麂皮靴；也是這等毛臉雷公嘴，朔腮別土星，查耳額顱闊，獠牙向外生。*」（明・吳承恩，1991，頁 731）。

第十七回章節內孫悟空介紹自己的身份說：「*你去乾坤四海問一問，我是歷代馳名第一妖。*」（明・吳承恩，1991，頁 213）。

第十四回章節內描述孫悟空頭上的金箍造形：「*伸手去頭上摸摸，似一條金線兒模樣，緊緊的勒在上面，取不下，揪不斷*」（明・吳承恩，1991，頁 181）。

第七十五回章節內描述孫悟空頭上的金箍材質與顏色：「*唐僧還恐不堅固，預先又上紫金箍。*」（明・吳承恩，1991，頁 949）。

孫悟空的身高在明·吳承恩《西遊記》百回本第三十七回章節故事中，本來縮小身形躲在小盒子裡的孫悟空在回復身，高時變大到三尺四五吋高的原始身高時，就停止長大，根據陰法魯與許樹安（1991）所提出的明代量尺的標準單位來換算三尺五吋就是現在的 119 公分。即使再高一點點，孫悟空的身高頂多 130 公分出頭。

孫悟空整個相貌的大略意思是毛色是黃色，頭戴猶如絲線一般細的紫金金箍，骨頭在外肉在內卻又臉上有毛，沒有腮，耳朵外張又生硬，往外長的獠牙，顴骨非常高，瞪大又有冒火感覺的一對黃眼睛，尖尖的嘴像雷公似的，額頭不是突出圓形，是向內凹陷的一個窟窿，文中形容到孤拐臉，孤拐是指腳踝與顴骨部位，形容臉上顴骨非常高（漢語辭典，1967），孫悟空曾經自稱皈依前的身份是隻妖猴，如果不看故事內容僅以造形感覺而言，“凹臉尖嘴”、“身軀鄙陋”、“相貌凶醜”、“毛臉雷公”是個反派形象。

2.2.1 孫悟空的經典造形

孫悟空整個成長過程當中，身上穿著的正式服裝有兩套，一套是四海龍王所送的武器與武裝，一套是唐三藏贈送的布衣套裝。即僧侶穿戴的連身長裙，加上腰間一件虎皮裙，腳踩麂皮靴，這是孫悟空兩個經典造形，如圖 1、圖 2：

圖 1. 西遊連環畫孫悟空布衣造形局部放大圖。圖片來源 ： 趙宏本、錢笑呆 （1963）。

圖 2. 西遊連環畫武裝孫悟空造形局部放大圖。圖片來源 ： 劉繼卣（1956）。

2.3 近代動畫電影裡面關於孫悟空的造形演變

陳建君、李明（2008）指出，中國第一個動畫形象的孫悟空 1941 年從萬籟鳴導演的動畫影片《鐵扇公主》中橫空出世，塑造了中華民族特有的對抗強權的英雄形象，如圖 3：

圖 3. 1940 年動畫電影《鐵扇公主》中的孫悟空造形。圖片來源 ： 常怡雯 （2017）。

徐振東（2013）指出，以孫悟空主角的西遊題材動畫影片在近代中國的發展分為三階段，分別是以 1941 年的《鐵扇公主》、1964 年的《大鬧天宮》以及 1985 年的《金猴降妖》等動畫影片為代表的傳統階段，如圖 4：

圖 4. 1961-1964 年動畫電影《大鬧天宮》中的孫悟空造形。圖片來源 ： 陳傳志 （2016）。

1998 年央視版的《西遊記》動畫影片為代表的過渡階段，2005 年《紅孩兒大話火焰山》2010 年《奪寶幸運星》2010 年《新版西遊記》為代表的顛覆階段，反映了不同時期的審美變遷，如圖 5：

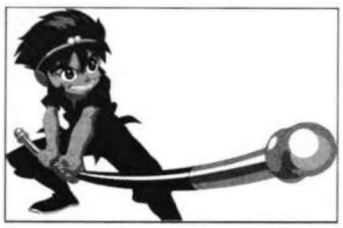


圖 5. 2010 年動畫影片《新版西遊記》中的孫悟空造形。圖片來源 ： 徐振東（2013）。

《大鬧天宮》的孫悟空造形猶如把代表中國傳統文化元素的京劇、壁畫等直接搬上電影螢幕上，甚至比較 1961 年到 1985 年的時期，孫悟空的造形設計也僅止於借用與傳承，沒有什麼改變，過渡階段的孫悟空造形脫離了臉譜式的形象，轉變成一位有精神的英姿勃發翩翩少年人形象，顛覆階段的孫悟空造形變成越演越小的特殊現象。

2.4 近代西遊記中孫悟空的設計困境與建議

黃玉、殷俊（2020）觀察近年來中國神話故事國產動畫電影發現，在盲目追求並符合真、善、美與符合經典造形的理念下，千篇一律的造形形象已經對觀眾形成了視覺轟炸，在審美過度與審美疲勞現象的作用下，為了滿足以醜為美的獵奇心態，“審醜”滿足了觀眾在這方面的需求，近代動畫創作者通過“陌生化”與“生活化”的手段，對孫悟空的造形設計注入了跳脫傳統的顛覆性元素，把神聖的形象重新建構成為荒誕而醜陋的陌生人，對觀眾們產生真實而陌生的深刻印象，更具真實感又不失經典形象配件的角色造形引發了廣大觀眾的共鳴，此即為“審醜化”的一個具體實現，《大聖歸來》中的孫悟空造形即為審醜化的代表案例，如圖 6：

圖 6. 電影《西遊降魔篇》與原著接近的孫悟空反派造形。圖片來源 ： 周星馳、今何在（2013）。

2.5 關於審醜

Bayley, Stephen（2013）以一把 0.45 口徑的柯特手槍為例，外型設計以端莊與尊嚴著稱，使配戴它的人都能得到身份提升的榮耀感，但是不論外型給人多少端莊尊榮的感覺，當它被用來從事殺戮與威脅並征服生命與尊嚴時，它終究會被認定是醜陋與邪惡的存在，是否貼近人性或違背人性成為美與醜的的界定關鍵，黃玉、殷俊（2020）說明審醜並不是單純的指外型醜陋，是把變形、怪異、扭曲等特點加入審美的對象，使之呈現脫離常規但卻又合乎尺度，顛覆並刺激受眾的感官與情感，並列舉 3D 動畫電影《史瑞克》、《海底總動員》與《怪獸電力公司》等造形設計精華，正是醜化的造形與貼近真實的性格缺陷用來刺激觀眾的反感與好奇情緒，這類善良正面的角色被賦予扭曲荒誕的外貌，不美麗卻沒有使人感覺反感，亦是另一種美的表達，這樣的美感更適合於塑造踏實並貼近生活的角色。

吳承恩在原著中對孫悟空的原始造形設定長期以來都被創作者們迴避，直到導演周星在 1995 年把孫悟空以貼近原著設定的反派個性與造形作為主軸發表在電影作品裡面開始，孫悟空最初始的風貌開始被大眾所認識與漸漸接受，反觀西方超級英雄的塑造，審醜的另類美學發展得非常成熟，蒐羅不同立場與族類造形，代表真善美的造形不在多數，造形走反派路線的正義超級英雄反而大受歡迎，如圖 7：

圖 7.《地獄怪客 2：金甲軍團，2008》。

圖片來源 ： IMDB 網站
<https://www.imdb.com/title/tt0411477/mediaviewer/rm3577387008/>（檢索日期 2021/08/02）

2.6 孫悟空造形未來的展望

2.6.1 漫威超級英雄美猴王

2021 年四月份，美國超級英雄品牌的漫威影業宣布，由華裔導演吳宇森接手拍攝真人版的漫威超級英雄美猴王《Monkey Master》電影，在文化代表性能發揮強大商機的國際多媒體重要戰場上，身為東方神話代言人的孫悟空果然沒有缺席，如圖 8：

圖 8. 漫威美猴王《Monkey Master》造形圖片。
圖片來源 ： COSMOPOLITAN 網站
<https://www.cosmopolitan.com/tw/entertainment/movies/g36021495/monkey-king-marvel/>
（檢索日期 2021/08/02）

擁有美式超級英雄品牌的 DC Comic 公司 2021 年 5 月推出了「美猴王 Monkey Prince」，畫作由 Bernard Chang 繪製，華裔編劇楊謹倫執筆，如圖 9：

圖 9. 「美猴王 Monkey Prince」造形圖。
（圖片來源 ： 玩具人網站。）
< https://www.toy-people.com/?p=60896>
（檢索日期 2021/08/02）

西遊記在世界文學的推廣尚屬於片段與寄託在宗教宣傳上，對於西遊記了解有限的美國影壇尚且嘗試著要對西遊記作改編，了解東方神話背景的我們也可以嘗試著把東方文化再包裝，把孫悟空打造成東方文化特色的超級英雄，行銷到世界舞台上。

2.6.2 賦予孫悟空超級英雄造形特色

陳曦（2020）建議，分析漫威超級英雄的能力種類，設定自神話背景的虛構神話人物雷神索爾，雖然最不現實，但是神話結構在地理與科學觀點做了貼近現實的連結，這巧妙的設定正好迎合最不缺神話素材的中國文化，條件如此匹配，東方神話體系裡也該有專屬的超級英雄。以上論述正好說明，超級英雄不是西方世界國家的專利，綜合以上建議，孫悟空與上述的建議皆符合，是東方超級英雄最相近的人選。

表 1. 分析超級英雄通常要具備七大組成要素：

1	有坎坷的身世背景或是孤兒身份。
2	擁有超能力或是崇高氣質與精神。
3	擁有強烈的正義感，守法。
4	擁有專有的造形外觀與獨特的裝備。
5	有雙重身分並隱姓埋名。
6	擁有愛國情操，並象徵著美國精神。
7	擁有合乎科學理論的超能力。

（參考資料來源：Richard Reynolds,1994）

以上特色僅有第四項與第五項與外在的造形設定有直接的關聯，對於外國觀眾而言，孫悟空所穿戴的一身金甲即代表民族文化特色，對於能彰顯強壯肌肉的緊身服裝，可以把貼身輕甲隱藏在強大厚重的韋馱天王戰甲內，可拆卸的兩套式樣即可兼顧東西方特色，塑造成東方超級英雄造形的想法是值得嘗試的。

2.7 角色設計的方法

在靈感獲取以及設計的方法上，參考 Ellen（2011）所提出的設計思考方式，Ellen 使用的設計程序是倚賴視覺化建構的概念圖型繪製。

以筆者本身多年與小說家以及布袋戲木偶雕刻師的溝通經驗而言，委託人由字面形容而轉換為圖象，溝通非常耗時，完成後的造形準確性與滿意度亦有限，在改以照片的輔助溝通後，所得到的效率最高，原因在於大多數的設計造形都是在生活上所見的圖像，經由腦中拆解成圖形零件後，再依照想像匯聚而成，想像的結果可以透過圖像照片來比對出圖像的看法，如具體的明星的照片或是長年蒐集的各類角色畫本與電影劇照等，都能輔助提案的人快速找到自己腦中想像的原始起點，把委託人想像的圖像照片找出匯聚成成品圖像，這樣的程序與 Ellen 所提出的強迫連結法與重新建構法非常符合，用來接受小說家委託或是對木偶雕刻師做說明的效果都是最好的，本研究也能用圖像匯聚的方式來達成具體又清楚的說明，此即本次的創作方法採用原因。

2.7.1 強迫連結法（Forced Connections）

設計師為獲取靈感，獲取更新奇的創意與設計的新花樣，採用強迫連結法的思考步驟，把設定好要設計的商品或是服務或是風格這類的題材，藉由腦力激盪的思考方式，先把完全沒關係也毫無聯想條件的幾樣事物用強迫性的思考方式聯想起來，在腦裡把這些元素相互碰撞，常常都會獲得意外的成果，強迫連結的發生可以參考執行步驟，首先要把要連結題材的圖形目標做好設定，然後把選定好的圖形目標做列表，要把需要的風格或是機能設定好，過程中把繪製的圖形裡矛盾與不合理的部位做整理或合理的再繪製，最後從這些交錯的概念圖形裡面，推演出自己理想的視覺創意圖形，此類脫離自己直覺程序的機械程序，常常能碰撞意料之外的創意畫面，亦是採用強迫連結法的優點。

2.7.2 重新建構法（Reconstruction）

創意時時都可以透過參考別人的創意而得到啟發，要把這些屬於他人的創意轉換成自己專屬的想法，並用自己的風格再繪製，轉換成屬於自己的創意，這是重新建構法的主要目的，首先是針對設定的目標來積極蒐集有吸引力的圖形素材，並拆解分析這些優秀素材的結構，瞭解這些過人創意的表達能力底下所蘊含的原理與組成原素，並能推演出這些創意的基礎想法與思考邏輯，拆解出來並瞭解它吸引力的由來，並把它的展現程序推演回來並重新繪製出來，重複以上的收集拆解與重繪的程序，這些重新繪製出的元件圖案就會組織成屬於自己的元件資料庫，再把這些元件重新堆疊成自己理想的成品，這類吸收轉換完成自訂風格的繪製程序，即是重新建構法的實現。

3. 原著設定版本孫悟空設計與製作

3.1. 製作流程

原始設定的孫悟空造形，製作的流程列表，如圖 10：

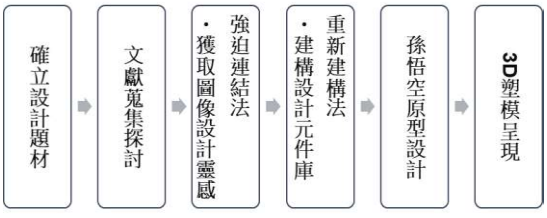


圖 10. 原著初始版本的孫悟空概念造形製作流程（圖片來源：本研究自繪）。

3.2. 強迫連結法-獲取圖像設計靈感

由文獻探討所蒐錄的孫悟空造形設定資訊，按照族類、磕額頭、骨頭在外、獠牙向外長、金睛火眼等五個反派妖猴造形項目整理成文字與圖像的對照列表，以供強迫連結法來做靈感參考，建立重新建構法所要用到的元件圖庫，如圖 11 至圖 25：

3.2.1 族類的研究方法說明

族類：靈明石猴並不存在現有已知的生物圖鑑當中，文獻資料中亦無圖樣可供參考。

圖 11. 猴類的身形 （圖片來源：本研究自繪）。

強迫連結所得的靈感：大唐三藏取經詩話記載，孫行者自稱「八萬四千銅頭鐵額獼猴王」，獼猴是最直接也最可能有關連的品種。

圖 12. 獼猴 （圖片來源：英國 DK 公司，2018）。

重新建構的圖畫元素：綜合總體設定，身高 120-130 公分外型鄙陋的獼猴，除矮小之外，看起來不是隻健康的獼猴。

圖 13. 矮小的獼猴 （圖片來源：本研究自繪）。

3.2.2 磕額頭的研究方法說明

磕額頭：形容額頭是內凹的一個窟窿，靈長類的黑猩猩有凸出的眉骨來對比，可得到類似的效果。

圖 14. 黑猩猩隆起的眉骨
（圖片來源：Ian Redmond，2005）。

強迫連結所得的靈感：眉骨在西洋人的特徵中比較隆起，在繪製獸人這類半人生物組合的時候，是刻意發揮的重要部位。

圖 15. 靈長類臉部眉骨區域劃分圖
（圖片來源：中塚 真，2014）。

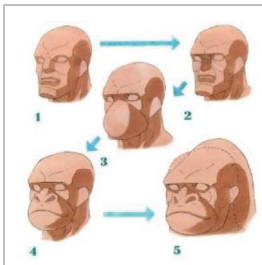
重新建構的圖畫元素：將眉骨的隆起價構誇大，與眼窩的落差加大，額頭稍作內凹使磕額頭的感覺會更符合設定。突起的誇張眉骨成為一個圖像元素。

圖 16. 隆起的眉骨部位 （圖片來源：本研究自繪）。

3.2.3 骨頭在外的研究方法說明

骨頭在外：骨頭在外面，肉在裡面，這樣的面貌設定比較像是僵屍或腐敗的屍體才有的模樣，以架空的生物設定來說，這充滿未知的挑戰。

圖 17. 母金剛猩猩的橫剖面模型 （圖片來源：Ian Redmond，2005）。



強迫連結所得的靈感：中塚 真（2014）提出：容貌的互換可以按照預設的切割線作拆分，再做置換繪圖，這也是遊戲生化角色的設計準則。

圖 18. 類人猿與人類的生物角色轉換分析圖 （圖片來源：中塚 真，2014）。

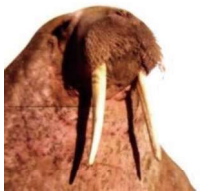
重新建構的圖畫元素：為飲食必須讓嘴巴部分保持封閉，鼻頭以上到整個磕額頭部位可以整個古頭外露，與超級英雄戴著的超帥面具意外相似。

圖 19. 像英雄戴著的超帥面具 （圖片來源：本研究自繪）。

3.2.3 獠牙向外長的研究方法說明

獠牙向外長：獠牙是猴子的基本配備，原著特意把獠牙做凸顯，必須找獠牙更巨大更顯眼的素材來做連結。

圖 20. Drill 獠牙 （圖片來源：京都大学霊長類研究所，2017） 。



強迫連結所得的靈感：巨大的獠牙能帶來強大殺傷力的壓力，要具有妖怪的感覺，除了大一號尺寸，還必須帶入神幻的感覺。

圖 21. 海象的獠牙 （圖片來源：英國 DK 公司，2018）。

重新建構的圖畫元素：獠牙有朝上與朝下的方向與曲直兩種感覺，都朝外面的方向長。

圖 22. 神獸的獠牙圖騰示意圖 （圖片來源：本研究自繪）。

3.2.5 金睛火眼的研究方法說明

金睛火眼：銳利的眼神與燃燒的效果是金睛火眼的元素之一，還可以在外部造形以及顏色搭配上發揮。

圖 23. 山魈持久、尖銳的目光 （圖片來源：英國 DK 公司，2018）。

強迫連結所得的靈感：中塚 真（2014）提出：獸人的眼眶與皮膚的交界線加粗後可提升眼神銳利效果，瞳孔越小感覺越恐怖，瞳孔越大感覺越可愛。

圖 24. 銳利眼神繪製說明圖 （圖片來源：中塚真，2014）。

重新建構的圖畫元素：銳利的感覺用瞳孔的尺寸來表達，跨越眼睛界線的隆起眉骨跟燃燒狀的眉毛都是神獸等級的角色提升魄力的優勢。

圖 25. 加上眉毛燃燒效果的銳利眼神 （圖片來源：本研究自繪）。

完成以上的強迫連結分析後，構成西遊記百回本所設定的美猴王所必要的建構元件圖，如圖 26：

圖 26. 美猴王所必要的建構元件圖表 （圖片來源：本研究自繪）。

3.3. 重新建構法-建構設計元素庫

原型設計採用 ADOBE 公司的影像處理軟體 PHOTOSHOP，搭配 WACOM 的繪圖板繪製，快速勾勒出以上元件庫所綜合出來的孫悟空影像，如圖 27：

圖 27. 自從容閒逸的形象裡捕捉出的參考形象（圖片來源：本研究自繪）。

以上圖為概念，再重畫一次，骨頭在外面的感覺，很像是戴著一頂骨頭形狀的頭罩，眼睛刻意的再挪往更深處，這樣的感覺跟 DC 英雄的蝙蝠俠非常相似，這也是本研究所意外發現的一個特別處，如圖 28：

圖 28. 面罩的感覺加上後的原始孫悟空造形完成圖 （圖片來源：本研究自繪）。

再補充道具與個性的古裝裝扮，成為西遊記前七章的齊天大聖造形，如圖 29：

圖 29. 原著版本妖猴齊天大聖孫悟空造形 （圖片來源：本研究自繪）

4. 孫悟空 3D 模型展示

本節將對孫悟空的原著造形 3D 塑模與超級英雄版本的孫悟空造形 3D 塑模做展示。

4.1. 孫悟空的原著造形 3D 塑模展示

3D 造形可以免除手繪以及空間感的誤差，使用 AUTODESK 公司的 3DS MAX 軟體為主要工具，根據參考造形特徵，把原始的齊天大聖圖像立體化，如圖 29、圖 30、圖 31：

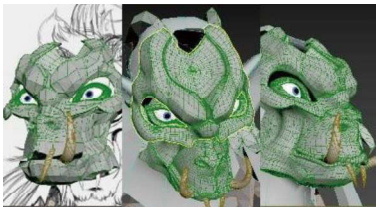


圖 29. 依循原著設定孫悟空無腮與骨頭在外 3D 臉部基礎骨架模型圖 （圖片來源：本研究自繪）。

在孫悟空的 3D 造形，在鎧甲下的渾身都將貼上棕黃色或淺棕色的毛髮，在 3D 動畫動作設計時時仍保有了表情、矯捷身段的猴性。

圖 30. 原著孫悟空骨架加上毛髮的 3D 臉部造形（圖片來源：本研究自繪）。

圖 31. 原著孫悟空的 3D 全身模型正面與側面圖（圖片來源：本研究自繪）。

4.2. 與其他版本的猴王造形比較

本研究所繪製的孫悟空妖猴造形與商業繪本的孫悟空造形作比較分析：

分析條件，初始版本的孫悟空以貼近原著的六項設定的符合數量作比較，符合數量多者佳。比較樣本以魯冰 （2020）的西遊記（經典名著彩繪版）朱延齡（繪）聯經出版公司。內取的猴王特寫圖片與本研究所繪製的版本做比較，如圖 32、圖 33：

圖 32. 商業插畫的猴王造形 （圖片來源：魯冰，2020）朱延齡繪插圖。）。

圖 33. 原著猴王圖 （圖片來源：本研究自繪）。

以原著的六個設定：骨頭在外、磕額頭、金睛火眼、一臉毛、腮、獠牙等特徵做比較，具有的特徵越多者為佳，如表 1：

表 2. 原著猴王的特徵比較表

特徵	骨頭在外	磕額頭	金睛火眼	一臉毛	腮	獠牙
原著設定	有	有	有	有	無	有
本研究	有	有	有	有	有	有
聯經彩繪	無	無	無	有	有	無

（本研究整理）

比較結果本研究的妖猴孫悟空較符合原著的六項特徵，聯經彩繪圖僅有兩項符合，本研究成果更符合原著所描述的特徵。

為與妖猴造形的猴性本質造成明顯對比，東方超級英雄造形的塑造以孫悟空三個構成因素當中的神性為基礎，把正派的真、善、美因素加入，與文獻中提及的經典造形比較接近，接受度亦可以被提升，參考 Richard Reynolds（1994）所提出的超級英雄七要素當中與外型有關聯的雙重身分與特色裝扮外型作為設計主軸。為符合平雙重分身的需求。臨時速寫一個戲班老人的形象來作為平凡人化身，如圖 34：

圖 34. 眉毛像火一般的神秘老武生 （圖片來源：本研究自繪）。

4.3. 孫悟空賦予超級英雄造形的繪製

本節將以強迫連結法－獲取圖像設計靈感；以重新建構法－孫悟空的武裝設計，繪製孫悟空超級英雄的造形。

4.3.1. 強迫連結法－獲取圖像設計靈感

東方超級英雄造形的塑造，把必要的構成元件再組建一次，以下將用超級體格的研究方法說明英雄造形的必要條件，再次應用強迫連結法，如圖 35 至圖 40：

超級體格：強健的肌肉是超級英雄必備的條件，成為散發強大感覺的重要元素。

圖 35. John Cenar 肌肉展示照 （圖片來源：Joe Weider，2014）。

強迫連結所得的靈感：明王及韋馱的強大感是來自身上的華麗鎧甲，亦是塑造東方超級英雄的重要文化元素。

圖 36 雙林寺韋馱菩薩穿著山文甲塑像 （圖片來源：王斌，1999）。

重新建構的圖畫元素：強大的肌肉與華麗戰甲搭配與連結，是本研究的挑戰。

圖 37. 超級英雄的肌肉元素圖 （圖片來源：本研究自繪）。

平凡人的化身：世人都不知道這個瘦小的老伯正是東方英雄鬥戰勝佛孫悟空在人間的化身。

圖 38. 神秘老武生（圖片來源：本研究自繪）。

強迫連結所得的靈感：不論是妖還是仙，獼猴特徵依然是唯一化妝依據的造形。

圖 39. 獼猴 （圖片來源：英國 DK 公司，2018）。

重新建構的圖畫元素：以正常人作為基礎來裝扮，毛髮分布得格局改變後的孫悟空，具有英雄氣慨造形做為起點。

圖 40. 一臉毛的東方超級英雄 （圖片來源：本研究自繪）。

構成本研究所要描繪的東方超級英雄孫悟空所必要的建構元件圖，如圖 41：

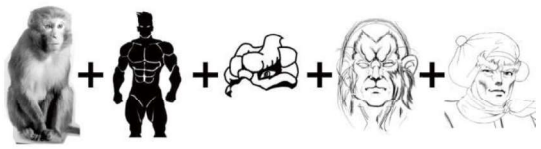


圖 41. 構成東方超級英雄孫悟空所必要的建構元件圖表 （圖片來源：本研究自繪）。

用相同的方法繪製，目標有預作設定，除保留猴子的生理特徵外，原始造形是設定為妖猴，新造形必須迎合成佛的要素以及受人景仰的威嚴，如圖 42：

圖 42. 把猴的特徵融入人與武俠的元素再稍作粗曠化處理的東方超級英雄孫悟空參考原型 （圖片來源：本研究自繪）。

最後加上骨頭在外的特徵，完成東方超級英雄版本的參考照型，如圖 43：

圖 43. 東方超級英雄鬥戰勝佛孫悟空 （圖片來源：本研究自繪）。

完成的概念圖還是有諸多比例與細部的修正的空間，將武裝的概念也呈現之後，再一併到 3D 軟體建構，以獲得更完整的修正結果。

4.3.2 重新建構法－孫悟空的武裝設計

依照文獻分析所得的孫悟空身高，比對新造形與配角完成的概念圖，如圖 44：

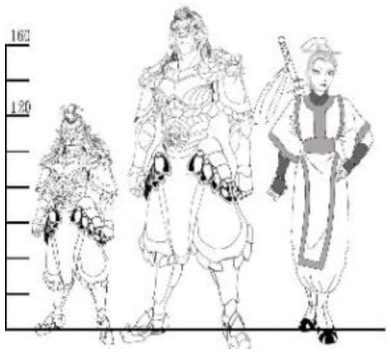


圖 44. 孫悟空身高，比對新造形與配角完成的比例圖 （圖片來源：本研究自繪）。

4.4. 孫悟空的超級英雄造形 3D 塑模展示

孫悟空的東方超級英雄造形 3D 塑模展示，如圖 45、圖 46：

圖 45. 孫悟空的東方超級英雄造形 3D T-pose 模型正側面圖 （圖片來源：本研究自繪）。

圖 46. 孫悟空的東方超級英雄造形 3D 臉部模型各角度圖（圖片來源：本研究自繪）。

5. 結論與建議

本研究經過文獻探討的分析與研究方法的實踐所完成的成果，經由與師長們與同儕的深入分析與意見回饋，針對本次創作的結論、對數位內容創作的貢獻，及優、缺點提出相關建議與說明。

5.1. 結論

依照強迫連結法與重新建構法的規範，確實有效率的把小說最初風貌的孫悟空具體呈現出來，這套研究方法對於把孫悟空塑造為東方超級英雄版本的打造呈現，亦能達成目標，對於擁有數百年文化內涵與神話背景元素的孫悟空來說，強迫連結法與重新建構法所能連結與建構的素材非常豐富，碰到的難處不在於要連結什麼，反而是要怎樣連結才能獲取更佳的結果，大部分商業用的孫悟空造形設計都是採用極為固定的有限素材與連結模式，主要原因在於西遊記題材的創作的都在取經的固定框架下作改編，當時空背景與要呈現的目標開始跳脫西遊框架之後，設計孫悟空的連結方式也會跳脫原有的連結的精心策劃作為，開始多元化的呈現出來，文化內涵與素材越是有深度，所連結建構出來的成果就會更具吸引力，以創作的角度來看待強迫連結法與重新建構法，即使不設計孫悟空，在素材豐富與連結目標明確的前提下，強迫連結法與重新建構法也能游刃有餘並有效率地完成任何其他題材的創作目標，但是受限於創作者本身對於角色的瞭解程度、本身的訓練年資、經驗與審美觀角度各不相同，相同的研究方法與連結素材所獲取的結論不會一致，這也是一個創作多元化的有趣結論。

本次創作研究的設計方向根據文獻探討所獲取的結論，內部設定保留孫悟空的真、善、美本質設定，外部造形設定不把孫悟空的造形作真、善、美的極致美化，遵循原著小說的初始設定，並對原著內容作深度發掘試圖找出孫悟空可能還未被發掘的造形元素以及特色，並以反派風格來作來作設計重點，使用 “審醜”的另類美感與”陌生化”的思考方向來為孫悟空設計一個完全不同風味的神獸造形，讓新造形的孫悟空配備上強悍的戰鬥意志與鋤強扶弱的正直信念再度回歸大眾，在東方超級英雄的塑造方面，保留文化特色的山文甲裝扮與融入超級體格所塑造的東方超級英雄造形，在對世界舞台做行銷的理念尚有不足，以邁出第一步的角度來看，期待能達到拋磚引玉，吸引更多有志的創作者一同參與的目地，以第四章的成果展示而言，成果亦符合本研究的設計思考方向。

5.2. 本研究對數位內容創作的貢獻

本研究對數位內容創作的四點貢獻具體說明：

(1) 研究方法的印證，強迫連結法與重新建構法在本次設計研究中作為創作設計的規範依據，將預計的兩個目標角色成功的呈現出來，本研究方法的應用，可以用來作漫畫與插畫從業人員的設計創作鍛鍊與落實，在講究創新與繼承優秀民族文化的傳統上，本方法的使用皆能有一定成效的將目標呈現出來。

(2) 本創作研究過程使用 2D 平面作初始的概念設計，再把具體的結論作為 3D 塑模的設計圖，進而完成設計，趕製模型的過程中意外的發現，3D 塑模亦可以使用重新建構法執行塑模的方法，以既有的元件庫來建構目標模型雖然已經是 3D 塑模的常態，但是比較起來，3D 的堆疊能力與效率強過 2D 非常多，使用概念過程如果能以 2D 設計元件庫的方式用 3D 的平台再做一次，可以獲得意外的成果，2D 與 3D 平台交錯使用之後的成果，再用 2D 技法重新發揮一次亦能在創作質量上發揮強大的視覺輔助機能，不同平台間的交替互相輔助，在視覺震盪的效率比單一平台的使用的效率要強上很多，這個使用經驗對於創作成果品質的提升是確定的。

(3) 本研究創作依循強迫連結法與重新建構法的規範所繪製的超級英雄孫悟空造形，所繪製出的成果保留石猴的先天生理結構，忠於原著小說所設定之原始猴王臉部造形元素，擬人化的堅定眼神展現孫悟空純真的本性，具有在戲劇裡表達人性與情感的能力，石猴與超級英雄的造形元素連結後，能把沉重的唐朝鎧甲輕便化與貼身化，壯碩的體格有達到超級英雄的強大感，達成厚重與敏捷條件並存的設計目標，突顯出神性的層面，保留經典造形的獨特辨識度以及跳脫舊設

計框架的嶄新造形，以上成果符合百年來構成孫悟空內在與外在的猴性、人性與神性等三個組成元素，並達成本次創作研究的目標。

(4) 本研究所創作出的初始版本孫悟空與東方超級英雄版本孫悟空造形，與近代商用版本的傳統孫悟空造形相似度確實有非常大的差異，有達成“陌生化”的目標，並擺脫刻意保留的傳統舊包袱，在不可任意改動的經典造形設計上依舊依循承繼傳統文化元素，深度發掘原著小說內深層的設定，不至於陷入老套的借鑑式與拿來式之類的舊思維，在孫悟空長達百年的角色設計歷史所做出的貢獻，一改長年以來商業設計對猴王施加百般美化討好觀眾的千篇一律設計模式，可以成為未來孫悟空造形設計發展的另一個全新的借鑑參考設計目標。

5.3. 製作建議

把整個創作研究流程做深入分析之後，對於本次的創作有以下三點建議：

(1) 本次 3D 塑模只使用到 3DSMAX 軟體，高面數模型的製作至使時間大都耗費在佈線上，建議可以加入 ZBRUSH 這類應用軟體可以快速製做複雜高面數模型加工的軟體，預計可以大幅度的提升製作效率並能節省時間。

(2) 初稿的階段與 3D 成品的感覺尚有差距，雖然脫稿改造是創作的必要插曲並常有意外收穫。若數位多媒體設計公司能夠提供良好的共同協作場域，專業分工效率的評估，可透過標準化的設計流程，提升設計工作效率。

(3) 以本研究所獲取的的風格朝完整的西遊世界或神魔仙俠世界做更大規模世界觀做設定，亦可以代入超級東方英雄展演舞台做創作方向。

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台灣數位媒體設計學會 入會申請書

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日期經過	年 月 日第 屆第 次理事會議審查：
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Submission of a manuscript implies that the paper has been neither submitted to, nor published in any other journal, in the same or similar form, in English or in any other language. Manuscripts previously published in a workshop, symposium, or conference can be submitted for consideration provided that the authors inform the editorial office at the time of submission, and that the manuscripts have undergone substantial revision.

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International Journal of Digital Media Design

《IJDMD 國際媒體數位設計學刊》徵稿訊息

第 14 卷第 1 期徵稿 (Call for papers)

本學會出版之 International Journal of Digital Media Design《IJDMD 國際數位媒體設計學刊》徵稿，稿件以隨到隨審為原則，敬請鼓勵踴躍投稿。

一、2021 年 IJDMD 國際數位媒體設計學刊經科技部期刊評比通過藝術學第二級期刊(Taiwan Humanities Citation Index，簡稱 THCI 核心期刊)，收錄於「臺灣人文及社會科學期刊評比暨核心期刊」期刊名單。投稿稿件採國內、外專業學者雙盲審查制(Double-blind Review)，中英文稿件皆可投稿。凡有關數位媒體設計之科技、理論、技術、文化、教學研究、藝術創作論述等相關議題論文，皆歡迎賜稿。

二、敬請 貴單位惠予轉知所屬相關單位；投稿相關規定及格式請參考臺灣數位媒體設計學會網站 http://www.dmd.org.tw。

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第 14 卷(2022)第 1、2 期 執行編輯**鄭永熏**教授。

E-mail: jamesyscheng@gmail.com

IJDMD (International Journal of Digital Media Design)

International Journal of Digital Media Design, Vol. 14 No. 1 Call for papers

Papers will follow the principle of review right away after receiving. All papers welcome.

I. IJDMD is the international journal of the Tier 2 journal in the Arts by the Taiwan Humanities Citation Index (THCI Core) Journals Evaluation of Ministry of Science and Technology during 2018 to 2020. With Double-blind Review from globe professionals, article is available for Chinese and English papers. Welcome all papers in relation to digital media design from science, technology, theory and culture, education and arts creation.

II. Please let your department deliver this messages to all your related department. All the submission format information is available on the official website of Taiwan Association of Digital Media Design (http://www.dmd.org.tw).

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IV. If you have the membership of Taiwan Association of Digital Media Design, the NT$5000 publication fee is included member fee NT $2000 and publication fee NT$3000.

V. Please make sure to fill all blanks in our membership application form, mail or e-mail and the application form and payment receipt to our secretariat to set up your personal file.

Volume14 (2022) executive editor, Prof. Yung-Hsun Cheng.

E-mail: jamesyscheng@gmail.com

Contents

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研究論文

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