International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:4, No:8, 2010

# The Feasibility of Augmenting an Augmented Reality Image Card on a Quick Response Code

Alfred Chen [1], Shr Yu Lu [2], Cong Seng Hong [3], Yur-June Wang [4]

***Abstract*****—**This research attempts to study the feasibility of augmenting an augmented reality (AR) image card on a Quick Response (QR) code. The authors have developed a new visual tag, which contains a QR code and an augmented AR image card. The new visual tag has features of reading both of the revealed data of the QR code and the instant data from the AR image card. Furthermore, a handheld communicating device is used to read and decode the new visual tag, and then the concealed data of the new visual tag can be revealed and read through its visual display. In general, the QR code is designed to store the corresponding data or, as a key, to access the corresponding data from the server through internet. Those reveled data from the QR code are represented in text. Normally, the AR image card is designed to store the corresponding data in 3-Dimensional or animation/video forms. By using QR code's property of high fault tolerant rate, the new visual tag can access those two different types of data by using a handheld communicating device. The new visual tag has an advantage of carrying much more data than independent QR code or AR image card. The major findings of this research are: 1) the most efficient area for the designed augmented AR card augmenting on the QR code is 9% coverage area out of the total new visual tag's area, and 2) the best location for the augmented AR image card augmenting on the QR code is located in the bottom-right corner of the new visual tag.

***Keywords*****—**Augmented reality, QR code, Visual tag, Handheld communicating device

## I. Introduction

QUICK Response code (QR code) was created by a Japan company, named Denso-Wave, approved by ISO in 2000. The QR code can store text, and it has no restriction on size. Its capacity of storage is normally from 3000 to 7000 characters. The QR code can still be decoded and completely read if it is defiled in an area of less than thirty per cent of the total area. The readers of QR code include conventional handheld communicating devices, such as mobile phone, personal digital assistant, etc. They are equipped with a built-in camera and decode software so that they can decode the concealed data of the code.

The QR code is constructed of normally square modules set out in a regular square array and shall consist of an encoding region and function patterns, namely finder, separator, timing patterns, and alignment patterns.

Authors are with Graduate School of Visual Communication Design, Kun Shan University, 71003, Taiwan
1alchen@mail.ksu.edu.tw ; phone: +886-6-336-3826; fax: +886-6-2902183, 2hamasakidiablo@yahoo.com.tw, 3htht0215@yahoo.com.tw, 4standywang0831@yahoo.com.tw

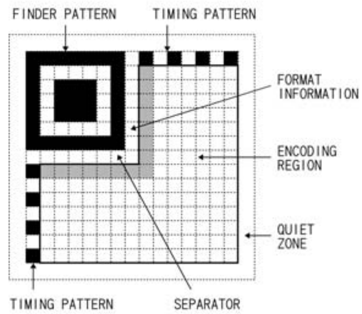
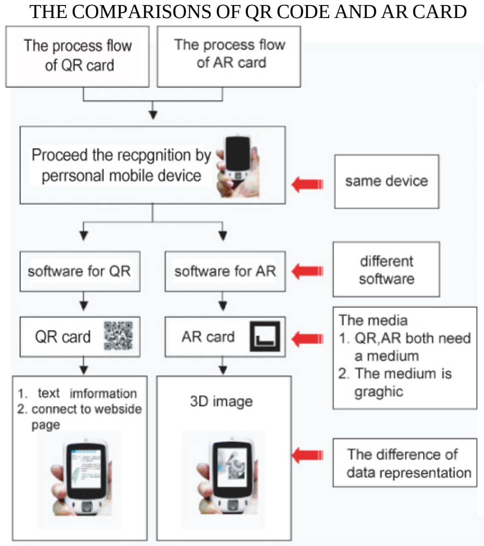



Fig. 1 Structure of Version M3 Micro QR Code Symbol

Function patterns do not encode data. [1] M3 Micro QR Code is one type of QR code, showed in Fig.1. Azuma（1997） took augmented reality as the diversification of virtual reality. AR allows observers to view virtual objects overlapping over the real world [2]. The equipment of AR requires AR image card, camera, virtual object, and the processing software and hardware as well. Mark Billinghurst (2005) indicated that AR image can be recognized by a personal mobile device [3]. Hence, despite of the recognition software, the physical requirements in hardware for QR and AR technologies can be same. The QR code decoding process and AR image card pattern recognition process have many in common. Comparisons of these two technologies have been made, as TABLE I.

TABLE I
THE COMPARISONS OF QR CODE AND AR CARD



## II. METHODOLOGY

### *A. The augmenting principles and the fault tolerant rate*

By undergoing the augmenting process, the four criteria must be followed, as following: 1) The demanding conditions for pattern recognition of AR image card are higher than the ones for a QR code. Hence, the simple form for an AR image card design is suggested. 2) It cannot augment a QR code on an AR image card, since an AR image card has no capability for fault tolerance. 3) It can augment an AR image card on a QR code under the condition of 30% fault tolerance rate. 4) The area of an augmented AR image card is as large as it can be for a better successful rate of pattern recognition.

Since a QR code allows a 30% fault tolerant rate, the augmented AR image card, in a square form, will be allowed to be augmented on encoding region of the QR code. However, its size is no longer than 30% coverage area of the total QR code area, as showed in Fig. 2.

Fig. 2 The AR image card augmented on a QR code

### *B. The fault tolerance*

In this research, the QR code is generated by the built-in software of QuickMark, under the four performance specifications of: 1) The fault tolerant rate, Q level (30%), for a QR code, 2) The characters based on OMI@UTF-8 system, 3) The 26 characters in English (from a to z) used for data content, and 4) The size of the QR code is 6.47 cm x 6.47 cm.

The AR image card is designed in a proportional matrix form. Its size is specifically in four different coverage areas of 1%, 4%, 9%, and 16%. They are marked respectively in four different gray tones, i.e. 1, 2, 3, and 4. The audit software for the AR image cards is PsQREdit, and the preliminary audit tests for each square form of AR image cards are undergone and showed as fig. 3.

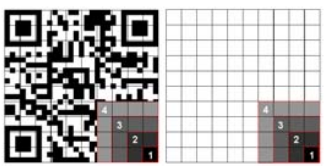
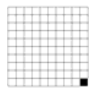
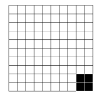
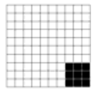
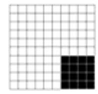


Fig. 3 Preliminary audit tests for the four augmented AR image cards on the QR code

In the preliminary tests, the four AR cards are respectively, one card each time, augmented on the bottom-right corner of the decoding region, as showed in TABLE II.

TABLE II
THE AUGMENTED IMAGE CARD COVERAGE AREAS IN 1%, 4%, 9%, AND 16%

| | |
|---|---|
|  |  |
| Augmented area (1%) | Augmented area (4%) |
|  |  |
| Augmented area (9%) | Augmented area (16%) |

After testing the four cards, the result shows the revealed data of the QR code are complete and correct.

## III. DEFINITION OF THE NEW VISUAL TAG

The newly developed visual tag contains a QR code and an AR image card, and the AR image card is augmented on the QR code.

### *A. The initial experiments for QR code*

The 26 characters in English (from a to z) are subjected to be input data for QR code. In the first series of tests, a single character (from a to z) is chosen, one character at a time, as an input for the QR code's content. Afterwards, the chosen characters, in quantity, are gradually increased from two to twenty-six, one increment each time, for the following series of twenty-five tests. The results show that the increasing quantity of the input characters will change the pattern of QR code. Meanwhile, when the input quantity of the characters increased to a certain level, the pattern of QR code will be changed in two situations: 1) A certain number of alignment patterns are appeared and increased, and 2) the finder patterns become smaller, as showed in TABLE III.

TABLE III
THE INPUT QUANTITY OF CHARACTERS AND THE CORRESPONDANCE OF THE PATTERNS

| | | |
|---|---|---|
| | | |
| The input quantity of the characters from 1 to11 | The input quantity of the characters from 12 to 74 | The input quantity of the characters from 75 to 241 |

It summarizes that 1) According to QuickMark QR Code Symbol Generator, the maximum quantity of the generated characters is 241, and 2) After the initial experiments, it indicates that the increasing quantity of the input characters will change the pattern of QR code. There are three typical patterns generated, as TABLE III. The quantity of the input characters from 1 to 11 results in the pattern at the left. The quantity of the input characters from 12 to 74 results in the pattern in the middle. The quantity of the input characters from 75 to 214 results in the pattern at the right. It also indicates that two thresholds for pattern changes are: 1) in-between 11and 12, and 2) in-between 74 and 75.

### *B. The subsequent experiments for QR code*

Among the three patterns in Table III, the pattern in the middle is chosen, as a subject, for the subsequent experiment, since the quantity of the input characters of a URL will normally not exceed 74. In order to peer into the more detailed changes of the patterns from 12 to 74, the three numbers of 27, 43 and 58 are considered to add on. Those five numbers are defined because they have a nearly equal interval, i.e. 15. Please refer to Fig. 4.


Fig. 4 The quantity of the input characters, respectively in 12,27,43,58 and 72, and their corresponding patterns

In order to define the augmented location and the most efficient size of an AR image card, the size of the QR code is firstly set by 14.5 cm × 14.5cm. Then, the AR image card area is set respectively in the coverage areas of 1%, 4%, 9%, 16%, and 25%. Please note that each area of those five square cards is still within the range of 30% fault tolerant rate. The procedure for undergoing the experiment is, in the first step, to augment the first AR image card, i.e. 1% coverage area, on the five QR code patterns of 12, 27, 43, 58, and 74 respectively. And the subsequently steps, from step 2 to 5 are the same procedure as step 1.

### *C. The audit templates*

First of all, create a 10 x10 lattices plan. And then test each of the augmented cards, respectively in 1% (1 x1 lattice), 4% (2x2 lattices), 9% (3x3 lattices), 16% (4x4 lattices), and 25% (5 x5 lattices). It results in the five audit templates, as showed in TABLE IV. Detailed descriptions are as follows: 1) Template for the 1% coverage area of AR image card: Marking the number of 1 on the lattice means that the lattice will be tested for one time only, 2) Template for the 4% coverage area of AR image card: Marking the number of 1 to 4 on the lattice means that the lattices will be tested for four times only, 3) Template for the 9% coverage area of AR image card: Marking the number of 1 to 9 on the lattice that means the lattices will be tested for nine times only, 4) Template for the 16% coverage area of AR image card: Marking the number of 1 to 16 that means that the lattices will be tested for sixteen times only, and 5) Template for the 25% coverage area of AR image card: Marking the number of 1 to 25 that means that the lattices will be tested for twenty five times only.

TABLE IV
AUDIT TEMPLATES FOR AR IMAGE CARDS' AUGMENTING TESTS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Template for the 1% coverage area of AR image card

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 |
| 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |

Template for the 4% coverage area of AR image card

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 |
| 2 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 4 | 2 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 3 | 6 | 9 | 9 | 9 | 9 | 9 | 9 | 6 | 3 |
| 2 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 4 | 2 |
| 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 |

Template for the 9% coverage area of AR image card

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 4 | 4 | 4 | 3 | 2 | 1 |
| 2 | 4 | 6 | 8 | 8 | 8 | 8 | 6 | 4 | 2 |
| 3 | 6 | 9 | 12 | 12 | 12 | 12 | 9 | 6 | 3 |
| 4 | 8 | 12 | 16 | 16 | 16 | 16 | 12 | 8 | 4 |
| 4 | 8 | 12 | 16 | 16 | 16 | 16 | 12 | 8 | 4 |
| 4 | 8 | 12 | 16 | 16 | 16 | 16 | 12 | 8 | 4 |
| 4 | 8 | 12 | 16 | 16 | 16 | 16 | 12 | 8 | 4 |
| 3 | 6 | 9 | 12 | 12 | 12 | 12 | 9 | 6 | 3 |
| 2 | 4 | 6 | 8 | 8 | 8 | 8 | 6 | 4 | 2 |
| 1 | 2 | 3 | 4 | 4 | 4 | 4 | 3 | 2 | 1 |

Template for the 16% coverage area of AR image card

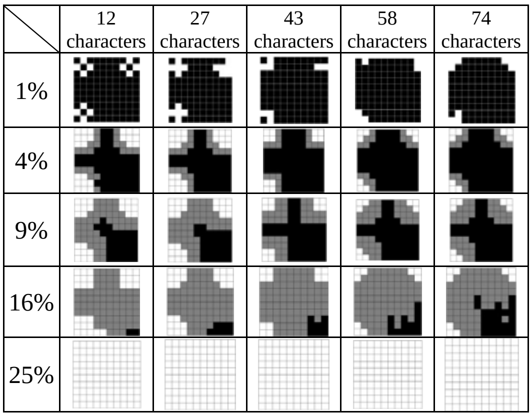
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 5 | 4 | 3 | 2 | 1 |
| 2 | 4 | 6 | 8 | 10 | 10 | 8 | 6 | 4 | 2 |
| 3 | 6 | 9 | 12 | 15 | 15 | 12 | 9 | 6 | 3 |
| 4 | 8 | 12 | 16 | 20 | 20 | 16 | 12 | 8 | 4 |
| 5 | 10 | 15 | 20 | 25 | 25 | 20 | 15 | 10 | 5 |
| 5 | 10 | 15 | 20 | 25 | 25 | 20 | 15 | 10 | 5 |
| 4 | 8 | 12 | 16 | 20 | 20 | 16 | 12 | 8 | 4 |
| 3 | 6 | 9 | 12 | 15 | 15 | 12 | 9 | 6 | 3 |
| 2 | 4 | 6 | 8 | 10 | 10 | 8 | 6 | 4 | 2 |
| 1 | 2 | 3 | 4 | 5 | 5 | 4 | 3 | 2 | 1 |

Template for the 25% coverage area of AR image card

### *D. The overlapping rates of AR image cards augmenting on QR codes*

In order to find the overlapping rates of AR image cards augmenting on QR code, systematic steps will be adopted. Firstly, build a matrix. Secondly, fill-up the column with the parameters of AR image cards, respectively in 1%, 4%, 9%, 16%, and 25% coverage area. Thirdly, fill-up the row with the parameters of QR codes, respectively in the quantity of input characters of 12, 27, 43, 58, and 74. Lastly, fill-up the matrix with QR code patterns. From each of the matrix, it points out that the data showed in each lattice (a total number of lattices is 100) will indicate the specific overlapping rate for an AR image card which augments on a QR code. As a result, the lattices in black color mean a 100% overlapping area, i.e. the most efficient area for augmenting a QR code. The lattices is gray color is 1~99% overlapping area, i.e. a near efficient area. The lattices in white color are non-efficient areas. The matrix will be showed in TABLE V.

TABLE V
MATRIX FOR ACQUIRING THE OVERLAPPING RATES OF AR IMAGE CARDS AUGMENTING ON QR CODE




## *E. The synthesis*

This section is to synthesize the data generated by Section 3.4. Systematic steps are as follows: 1) Step 1: Retrieve the five patterns from the first row of the matrix in TABLE V, 2) Step 2: Overlap the five patterns. Please refer to the graph in the middle box in Fig. 5, 3) Step 3: Accumulate the data from the five overlapped patterns. The ultimate pattern for the 1% coverage area of AR image card is acquired. Please refer to the far-left pattern on the bottom part in Fig. 5, and 4)Step 4: Undergo the synthesizing work for the 2nd to the 5th rows of the matrix, as the same procedure as the 1st row did.

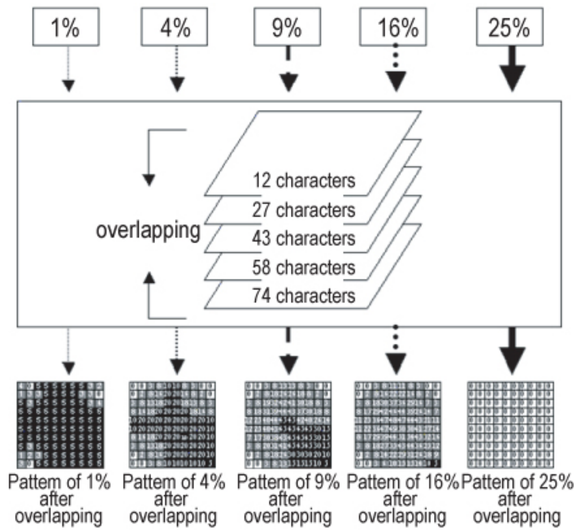


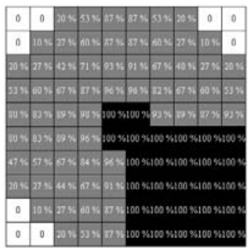

Fig. 5 The synthesis procedure for generating the ultimate patterns

After the step 4, the ultimate patterns for the 4%, 9%, 16% and 25% coverage areas of AR image cards are acquired. Please refer to the four patterns on the bottom part in Fig. 5. It is noted that the most efficient area (location) for augmenting an AR image card on a QR code, with 100% overlapping, will be showed in the lattices with color in black.

# IV. RESULTS

For QR code which has the input characters of 12~74, the most efficient area (with100% overlapping) for a 1% (1x1 lattice) AR image card to augment has covered 81% of the total QR code area. The most efficient area (with100% overlapping) for a 4% (2x2 lattices) AR image card to augment has covered 55% of the total QR code area. The most efficient area (with100% overlapping) for a 9% (3x3 lattices) AR image card to augment has covered 28% of the total QR code area. The most efficient area (with100% overlapping) for a 16% (4x4 lattices) AR image card to augment has covered 2% of the total QR code area. The most efficient area (with100% overlapping) for a 25% (1x1 lattice) AR image card to augment has covered 0% of the total QR code area. Accordingly, when the AR image card is minimized to 1% and 4%, the coverage area is large enough but the AR image card image is too small to utilize. When the AR image card is minimized to 16%, the coverage area is too small (2%), and when the image is minimized to 25%, there is no area covered. As a result, 1%, 4%, 16%, and 25% coverage areas are not good solutions. When the AR image card image is minimized to 9% (3x3 lattices), the covered area is 28%. Thus, the AR image card image is large enough for a handheld communicating device to recognize and the resolution of the AR image card is good too. In summary, the 9% (3x3 lattices) coverage area of the AR image card is an optimal solution, and the best location for an AR image card to augment is the bottom- right corner, as in TABLE VI.

TABLE VI
ALLOCATIONS FOR MOST EFFICIENT AREA OF AN AUGMENTED AR IMAGE CARD AUGMENTING ON A QR CODE WHICH HAS THE INPUT CHARACTERS OF 12-74



The most efficient area (with100% overlapping) for a 9%(3x3 lattices) AR image card

# V. DISCUSSION

One of the objectives of this research is to analyze the location of an AR image card augmenting on a QR code. By screening the coverage percentage, the authors are able to determine the coverage provided by QR code. QR code tolerates a fault rate as high as 30%. The fault area can be concentrated or dispersed. A dispersed fault will not result in a QR code malfunction as long as the fault is lower than 30%.

Based on this feature, the authors suggest that augmenting an AR image card image on a QR code is highly feasible. The AR image card however cannot be dispersed and is required to be presented as a square. The actual operations of the new visual tag reading process will be illustrated, as in Fig. 6.

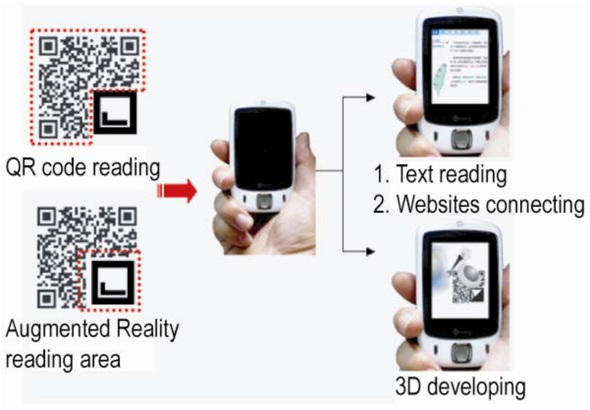



Fig. 6 Illustrations of the revealed data of a QR code and AR pattern recognition displayed on a handheld communicating device

## VI. CONCLUSION

The objective of this research is to augment an AR image card on a QR code so that a QR code will present real time interactive images. Based on the features of QR code coding and AR pattern recognition, the methods to present the revealed information vary. In lights of this, this research involves an analysis of the relations between the areas of QR code and AR image card. By doing so, a systematic test has been carried out. As a result, augmenting an AR image card on a QR code is feasible. The major contributions of this research include: (1) defining the optimal solution for an AR image card's area augmented on a QR code, and (2) defining the optimal solution for the location of an AR image card augmented on a QR code.

## REFERENCES

[1] ISO/IEC CD18004, ISO/IEC JTC 1/SC 31 N1915, Information technology-Automatic identification and data capture techniques-QR code 2005 bar code symbology specification, 2005, pp. 9

[2] Ronald T. Azuma , 1997 , A Survey of Augmented Reality , Azuma, Ronald T. A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 6, 4 (August 1997), 355 – 385

[3] Mark Billinghurst , 2005 , Face to Face Collaborative AR on Mobile Phones, Proceedings of the 15th International Conference on Artificial Reality and Telexistence (ICAT 2005), Dec 5th - 8th, 2005, Christchurch, New Zealand, pp. 164-171

**Alfred Chen** was born in Tao-Yuan, Taiwan on January 12, 1948. He is currently served as Professor of the Graduate School of Visual Communication Design, College of Creative media, Kun Shan University in Taiwan. His professional experiences have included the former Dean of College of Creative Media at Kun Shan University in Taiwan, the Professor and Head of the Department of Industrial Design, National Cheng Kung University in Taiwan, the Senior Research Associate, Design Processes Lab, Illinois Institute of Technology, USA, and Visiting Lecturer, Department of Design, The University of Kansas, USA.