ICCGI 2018

The Thirteenth International Multi-Conference on Computing in the Global Information Technology

ISBN: 978-1-61208-641-5

June 24 - 28, 2018

Venice, Italy

ICCGI 2018 Editors

Claus-Peter Rückemann, Leibniz Universität Hannover / Westfälische Wilhelms-Universität Münster / North-German Supercomputing Alliance (HLRN), Germany

ICCGI 2018

Forward

The Thirteenth International Multi-Conference on Computing in the Global Information Technology (ICCGI 2018), held between June 24, 2018 and June 28, 2018 in Venice, Italy, continued a series of events covering a large spectrum of topics related to global knowledge concerning computation, technologies, mechanisms, cognitive patterns, thinking, communications, user-centric approaches, nanotechnologies, and advanced networking and systems. The conference topics focused on challenging aspects in the next generation of information technology and communications related to the computing paradigms (mobile computing, database computing, GRID computing, multi-agent computing, autonomic computing, evolutionary computation) and communication and networking and telecommunications technologies (mobility, networking, bio-technologies, autonomous systems, image processing, Internet and web technologies), towards secure, self-defendable, autonomous, privacy-safe, and context-aware scalable systems.

This conference intended to expose the scientists to the latest developments covering a variety of complementary topics, aiming to enhance one's understanding of the overall picture of computing in the global information technology.

The integration and adoption of IPv6, also known as the Next Generation of the Internet Protocol is happening throughout the World at this very moment. To maintain global competitiveness, governments are mandating, encouraging or actively supporting the adoption of IPv6 to prepare their respective economies for the future communication infrastructures. Business organizations are increasingly mindful of the IPv4 address space depletion and see within IPv6 a way to solve pressing technical problems while IPv6 technology continues to evolve beyond IPv4 capabilities. Communications equipment manufacturers and applications developers are actively integrating IPv6 in their products based on market demands.

IPv6 continues to represent a fertile area of technology innovation and investigation. IPv6 is opening the way to new successful research projects. Leading edge Internet Service Providers are guiding the way to a new kind of Internet where any-to-any reachability is not a vivid dream but a notion of reality in production IPv6 networks that have been commercially deployed. National Research and Educational Networks together with internationally known hardware vendors, Service Providers and commercial enterprises have generated a great amount of expertise in designing, deploying and operating IPv6 networks and services. This knowledge can be leveraged to accelerate the deployment of the protocol worldwide.

The conference had the following tracks:

- Information technology
- Mobility and multimedia systems

We take here the opportunity to warmly thank all the members of the ICCGI 2018 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the

authors who dedicated their time and effort to contribute to ICCGI 2018. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

We also gratefully thank the members of the ICCGI 2018 organizing committee for their help in handling the logistics and for their work that made this professional meeting a success.

We hope that ICCGI 2018 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in the field of computing in the global information technology. We also hope that Venice, Italy provided a pleasant environment during the conference and everyone saved some time to enjoy the unique charm of the city.

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Table of Contents

Conceptualizing and Validating Information Security Culture as a Multidimensional Second-Order Formative Construct

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***Abstract*— This paper discusses a pilot study on conceptualization and validation of Information Security Culture (ISC) as a multidimensional second-order formative construct. The concept was developed in our previous works, and is based on widely accepted concepts of Organizational Culture and ISC. The model is validated using samples from employees of one Malaysia Public University. The Partial Least Squares Approach to Structural Equation Modeling (PLS-SEM) using Smart-PLS software was used to model and analyse the data. The ISC construct was treated as reflective-formative second-order construct and analysed using the latest approach in PLS-SEM. The findings empirically support the conceptualization and validation of ISC as a reflective-formative second-order construct with all seven dimensions being significant in contributing to the underlying concept of ISC. The study contributes to the ISC literature by providing new insights on the conceptualization, operationalization and validation of ISC the concept based on widely accepted concepts and approaches.**

Keywords- ISC concept; reflective-formative second-order; PLS-SEM.

I. INTRODUCTION

Due to increasing number of security breaches and attacks caused by employee's behavior, scholars and experts recommended practitioners to cultivate Information Security Culture (ISC) in guiding the security behavior in an organization. A number of studies related to ISC have been conducted to utilize this culture ranging from understanding of ISC to the development and validation of ISC frameworks and assessments [1]. However, there is still unclear what are the comprehensive guidelines to cultivate the ISC that effectively will influence employee's security behavior. Moreover, there is no common understanding of what ISC is and what factors or dimensions should be used to conceptualize ISC [2].

In terms of concept, generally, there are two ways of conceptualization found in the literature. The first approach is by using a general construct with particular number of reflective items. Although this approach is mostly used in the literature, there are some limitations pertaining to the applicability of the items to represent the elements or aspects of ISC cultivation. Since it is a reflective construct, the items or indicators used to measure the ISC construct are representing similar aspect of ISC only. This is because the items for a reflective construct are interchangeable [3]. As a result, these items could not be used to represent the particular distinctive aspects of ISC and the findings from this type of ISC conceptualization could not be utilized as aspects to be used in ISC cultivation. Furthermore, this approach is not comprehensively representing the actual meaning of the ISC itself because ISC is a culture that should be cultivated by multiple aspects. The second approach is by conceptualizing ISC as a multidimensional formative second-order construct with a particular number of first-order dimensions. In this way, the ISC construct is measured by several different aspects of ISC that form the concept [4]. This second approach of conceptualization provides more clear indications on the aspects that could be used as guidelines and strategies in ISC cultivation compared to the first approach.

This paper discusses ISC as a multidimensional second-order formative construct by proposing and validating the ISC concept that was developed in our previous works [5][6]. Section II discusses literature review and the conceptualization of ISC concept followed by the methodology used to validate it in Section III. Section IV presents results and analysis of data followed by the discussion of findings in Section V. Section VI justifies limitations of the study and finally the conclusion is presented in Section VII.

 ISBN: 978-1-61208-641-5

II. LITERATURE REVIEW AND MODEL DEVELOPMENT

There are many definitions of ISC in the literature. [7] in his systematic literature review on ISC studies has found that most of the ISC definitions were related to the model of Organizational Culture by [8] in one way or another. [9] defines ISC as the belief of individual employees on the value of complying with information security standards and policies. The latest definition by [10] refers to ISC as the collection of perceptions, attitudes, values, assumptions, and knowledge that guide the human interaction with information assets in [an] organization with the aim of influencing employees' behavior to preserve the information security.

Although there is quite a number of definitions, [1] suggested that there seems to be a common understanding that ISC "consists of a shared pattern of values, mental models and activities that are traded among an organisation's employees over time, affecting information security". In terms of ISC conceptualization, there are basically two approaches available in literature. The first one is in the form of general aspect of ISC construct measured by several reflective indicators such as in [11][12]. The second conceptualization approach treats ISC as a multidimensional second-order construct, such as in [13][14]. According to [15], "a multidimensional construct is a single theoretical concept that is measured by several related constructs". Using this second approach, ISC is conceptualizing as a Higher-Order Construct (HOC) consisting of several lower-order latent constructs. These lower-order latent constructs are the indicators of ISC construct, where constructs are described as multidimensional when their indicators are themselves latent constructs [16].

Compared to the first approach, the conceptualization of multi-dimensional second-order is useful when a greater specificity of understanding is warranted in case of a theoretical construct [17]. [18] in their security behavior study has suggested that whereas two or three measurement items might suffice to define a construct of peripheral interest, a multi-dimensional construct allows researchers to develop items that describe a construct in terms of multiple sub-constructs and making the nature of the construct clearer and more visible. Moreover, ISC is a complex concept and according to [16][19], a complex concept should be modelled as a multidimensional construct so as to permit a more thorough measurement and analysis. This is consistent with [20] that suggested ISC security culture is a multidimensional concept that has often been investigated in a simplistic manner.

In our previous studies [5][6], we adopted the general concepts of Organizational Culture by [8] and ISC by [21] to formulate the dimensions used to represent the ISC concept, as illustrated in Figure 1. These works produced an ISC concept in seven dimensions, namely Procedural Countermeasures (PCM), Risk Management (RM), Security Education, Training and Awareness (SETA), Top Management Commitment (TMC), Monitoring (MON), Information Security Knowledge (ISK) and Information Security Knowledge Sharing (ISKS).

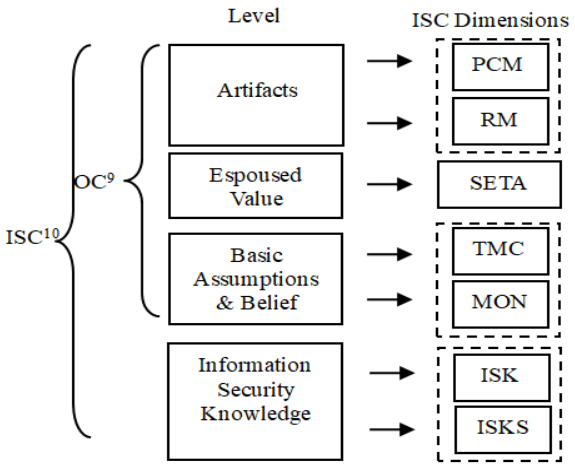

Figure 1. Formulation of ISC Dimensions [6]

Review of literature also revealed that the ISC concept is associated with these seven dimensions as discussed in [5] [6]. In order words, there are theoretical and empirical findings that suggest all the seven dimensions are influencing ISC. Although these dimensions are conceptually distinct, at a more abstract level, each can be viewed as describing a different facet of the overall construct of ISC [16][22][23]. These seven dimensions are forming the ISC construct, suggesting that the relationship between the ISC construct and its lower-order constructs is formatively similar to prior study [14]. This type of relationship is also referred to as aggregate by [16]. An aggregate construct 'combines or aggregates specific dimensions into a general concept', with the relationships flowing from the dimensions to the construct [24].

III. RESEARCH METHOD

A. Measures

This pilot study employed survey methodology to validate the proposed ISC model. Table I shows a summary of items used in this study to measure the respective constructs of ISC dimensions. The total measures were 30 in the questionnaire to represent the seven ISC dimensions. According to the table, most of the measurement items in this study are taken directly from prior tested and validated studies. The usage of previously validated instruments is strongly recommended in information system research [25] and it will increase and assure the content validity and reliability of the items used for the constructs in the study [26]. Only items of ISK were not directly adopted from the previous studies. The development of the items for this construct was based on literature analysis on this construct particularly in [21][27]–[30]. Additionally, the existing

 ISBN: 978-1-61208-641-5

scales in the literature also adapted in developing the items. All items were captured using a 7-point Likert scale ranging from (1) Strongly Disagree to (7) Strongly Agree to provide a more accurate view of their attitudes and perceptions [31]. Although most of the items in the questionnaires were adopted and adapted from the previous studies, a series of pre-tests have been conducted to ensure the validity for the context of this study. The responses from these tests were used to improve and refine the questionnaires.

TABLE I. SUMMARY OF ITEMS USED

Construct	Sources
PCM	[32]; [33]
RM	[30], [34]
SETA	[30], [34]
TMC	[35], [36]
MON	[32], [33], [14]
ISK	Adapted from [30], Self-definition by referring to [21], [27], [28]
ISKS	[37]

B. Sample Design and Data Collection

The data for this pilot study are collected using an online survey conducted for the duration of two weeks at one selected public university in Malaysia. The questionnaires' survey is designed using Google form and all responses are stored in the Google drive. In this cross-sectional survey, the invitations to participate were sent to respondents via e-mail with the survey's questionnaires attachment.

Since this is a pilot study conducted as a preliminary test before the actual study, the survey was targeted to get a minimum sample size that was appropriate to validate the model. The survey managed to get 92 respondents. Five invalid responses were removed from 92 due to having the same responses to all the questions (straight lining) and outliers. The final accepted samples were 87.

Specifically, the sample size calculation for this study has employed statistical power and effect size as suggested by [3] and recommended by [38]. This rule takes the number of maximum arrows pointed to a construct in the model, significance level and R^2 into consideration in calculating the minimum sample size. In our research model, since the maximum arrow pointed to ISC is the maximum, which is 7, according to [38], the minimum sample size of 80 is required to achieve a statistical power of 80% for detecting R^2 values of at least 0.25 (with a 5% probability of error). Therefore, 87 samples are appropriate for this study.

The ISC concept in this study is operationalized as a formative second-order construct formed by seven dimensions of first-order constructs. Each dimension is representing a strategy or principle element of ISC in an organization. This is consistent with [39] that used lower-order constructs to represent dimensions of strategic key components of instrumental and symbolic constructs. By using this approach, we could analyze the weights of the lower-order constructs to examine their relationship with ISC so that we could know which dimensions have relevance and significance in contributing to the ISC concept.

IV. RESULT AND ANALYSIS

A. Common Method Bias

Since data for the dependent and independent variables are provided by the same respondent, there is possible bias called Common Method Bias (CMB) or Common Method Variance (CMV) in the data collected. To test this bias, Harman's Single Factor Test [40] has been conducted. An unrotated factor analysis of all items yielded seven factors, the largest of which accounted for 47.55 percent of the variance. As an additional test, the correlation matrix [41] was examined to identify any highly correlated constructs ($r > 0.90$). The results have shown that all constructs had correlations below the threshold, which is less than 0.90. From these two tests, we conclude that the CMV bias is not a serious threat in this study.

B. Respondents' Profiles

Table II shows the profiles of respondents involved in this study. The respondents have a fair distribution of gender, with the majority of them being Malay. Most of them work in academics, followed by administration and management employees. In terms of highest academic qualification, the majority of the respondents had a Bachelor Degree or higher. The majority of the respondents had more than 5 years' experience working at this university.

TABLE II. RESPONDENTS' PROFILES

Demographic profile		N=87	Valid percentage (%)
Gender:	Male	39	44.8
	Female	48	55.2
Age:	18 - 24	2	2.3
	25 - 34	37	42.5
	35 - 44	38	43.7
	45 - 54	9	10.3
	55 and above	1	1.1
Race:	Malay	80	92
	Chinese	4	4.6
	Indian	1	1.1
	Others	2	2.3
Highest Education:	PhD	23	26.4
	Masters	18	20.7
	Bachelor Degree	27	31
	Diploma	10	11.5
	College	5	5.7
	Secondary School	4	4.6
Work experience:	Less than 2 Years	13	14.9
	2 to 5 Years	20	23
	5 to 10 Years	22	25.3
	10 to 20 Years	31	35.6
	20 Years and over	1	1.1
Service Type:	Academic	36	41.4
	Management	24	27.6
	Administration/Support	27	31

 ISBN: 978-1-61208-641-5

In summary, these demographic profiles show that the sample consists of appropriate sampling across the organization.

C. Data Analysis

The study employed the PLS-SEM to validate the model. The main reason is the model constitutes both reflective and formative constructs and also violates the assumption of multivariate normality [42][43]. PLS-SEM also has been commonly used by different scholars and provides a robust way to analyse the survey data [44][45]. Furthermore, PLS-SEM requires small sample sizes to conduct a valid analysis [46] compared to other techniques and all these criteria made PLS-SEM the most appropriate technique to be used in this pilot study. The Smart PLS (version 3.2.4; [47]) software was used to run the analysis by applying the technique of bootstrapping in order to evaluate the factor loadings' significance and path coefficients. Following the widely adopted two-step approach to SEM [48], the quality of the measurement model for all first-order constructs and second-order constructs were assessed first to ensure the validity and reliability of the measurements. Then, the structural model was analyzed by estimating the paths between the model's constructs determining the significance of path relationships.

1) Estimation of HOC in PLS-SEM through Repeated Indicator Approach

In repeated indicator, a higher-order latent variable can be constructed by specifying a latent variable that represents all the manifest variables of the underlying lower-order latent variables [49]–[51]. In this study, the higher-order factor, which is the ISC construct, is created using the indicators of its lower-order factors, which are PCM, RM, SETA, TMC, MON, ISM and ISKS. Table III shows ISC as a second-order construct constitutes seven dimensions of PCM, RM, SETA, TMC, MON, ISK and ISKS as underlying first-order constructs, each with their specific manifest variables.

By using this approach, the estimation of all the latent variables could be done simultaneously rather than estimating the higher-order and lower-order constructs separately [52]. Therefore, this estimation will avoid the interpretational confounding by taking the whole nomological network into consideration [39]. This approach is suitable since the primary objective of this study is to investigate the relationships of seven dimensions towards the ISC concept, which determines the appropriateness of these dimensions in representing the ISC concept.

TABLE III. SUMMARY OF ITEMS

Cultural Dimensions (First- Order Constructs)	Manifest Variables of First-Order Constructs	Number of Manifest Variables
PCM	PCM1, PCM2, PCM3, PCM4	4
RM	RM1, RM2, RM3, RM4	4
SETA	SETA1, SETA2, SETA3, SETA4	4
TMC	TMC1,TMC2, TMC3, TMC4	4
MON	MON1, MON2, MON3, MON4	4
ISK	ISK1, ISK2, ISK3, ISK4, ISK5	5
ISKS	ISKS1,ISKS2,ISKS3,ISKS4,ISKS5	5
Total items:		30

Specifically, this study employed repeated indicator approach with Mode A and path weighting scheme to model the second-order factors in the PLS analysis. According to [53], Mode A corresponds to correlation weights derived from bivariate correlations between each indicator and the construct. Mode B corresponds to regression weights, the standard in ordinary least squares regression analysis. Formative type models are commonly estimated by using Mode A for the repeated indicators, in the case the first-order constructs are reflective [53]–[55]. Furthermore, Mode A is more suitable since the aim for this particular assessment is to validate the relationship between each dimension with ISC concept rather than the regression of dimensions towards the ISC concept. In this study, since the seven ISC dimensions have been taken as the reflective first-order construct but as formative indicators for the second-order construct, therefore, Mode A was used for the higher-order repeated indicators.

2) Assessment of Measurement Model

Figure 2 shows the factors' loadings and path coefficient obtained from the PLS-Algorithm. Table IV shows the results of Cronbach's Alpha, Composite Reliability (CR) and Average Variance Extracted (AVE) that measures all items for first-order constructs. It shows that Cronbach's Alpha for each construct exceeds the threshold of 0.70 [56], AVE is greater than 0.50 [26] and CR is greater than 0.80 [55]. This means that the measurements are acceptable. In terms of loadings, all items are loaded highly on their own latent variable, and thus all measurements have satisfactory levels of reliability.

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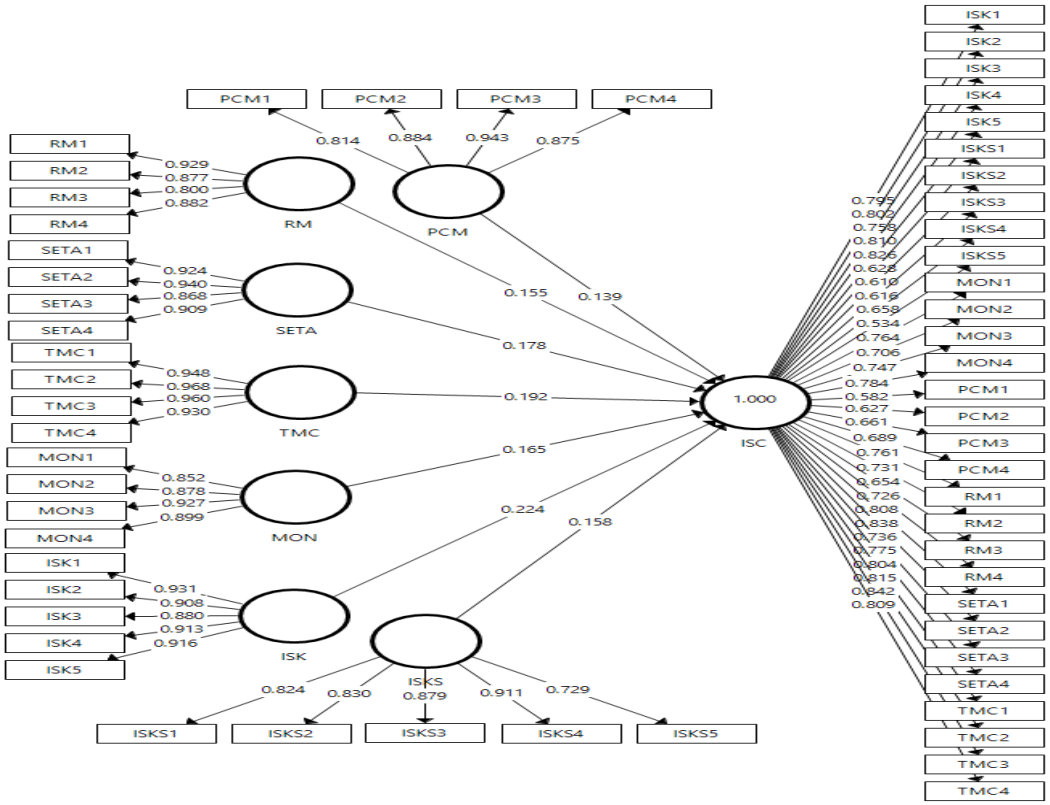

Figure 2. Factor Loadings and Weight

TABLE IV. COMPOSITE RELIABILITY AND VALIDITY

Construct	Cronbach's Alpha	CR	AVE
PCM	0.902	0.932	0.775
RM	0.895	0.927	0.762
SETA	0.931	0.951	0.830
TMC	0.965	0.975	0.906
MON	0.912	0.938	0.792
ISK	0.948	0.960	0.827
ISKS	0.891	0.921	0.700

The analysis of discriminant validity using Heterotrait-Monotrait ratio of correlations (HTMT) revealed that all values are below 0.90 [57], which indicates that discriminant validity has been established for all first-order constructs in the model.

3) Second-Order Construct Assessment

In assessing ISC as a second-order formative construct, this study used the recommendation in [58], by incorporating 3 evaluations, which are convergent validity; collinearity issues; as well as significance and relevance of formative indicators.

In measuring convergent validity, a global item of ISC that has been collected together in data collection was used to evaluate the path coefficient of the ISC construct, as illustrated in Figure 3. The result shows that the path coefficient is more than 0.70 and this suggests that the convergent validity was established.

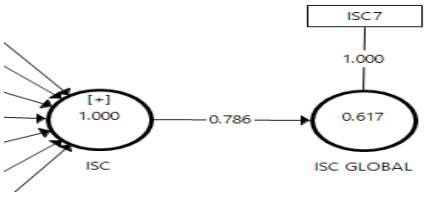

Figure 3. Convergent Validity Assessment

In terms of collinearity, Table V shows that the variance inflation factors (VIF) values for all ISC dimensions range from 1.95 to 3.75, which are below 5, thus indicating satisfactory reliability [59]. The results therefore, did not indicate a multicollinearity problem and support the formative nature of ISC.

TABLE V. WEIGHTS, T-VALUES AND VIF

ISC	Weight	t-value	VIF
PCM	0.139	11.925	2.018
RM	0.155	12.880	2.702
SETA	0.178	18.193	3.156
TMC	0.192	17.034	2.843
MON	0.165	15.543	2.965
ISK	0.224	16.851	3.754
ISKS	0.158	8.599	1.949

Note: Critical t values ***2.57 (significance level= 1%)

 ISBN: 978-1-61208-641-5

Table V also shows that the weight of each ISC dimension is above the recommended value of 0.10 [49]. All these weights of formative indicators also have significant t-values and have provided an empirical support to retain all the indicators [60].

Finally, in order to show the model's predictive relevance, a blindfold procedure has been done. The Q^2 values estimated by the blindfold procedure represent a measure of how well the path model can predict the originally observed values. The results of this procedure revealed that Q^2 value of ISC construct is more than 0.35 [3] and this implies that the exogenous constructs have large predictive relevance for ISC construct.

V. DISCUSSION

This pilot study has provided several important findings to be highlighted. First, since the measurement model assessments indicate that all items have passed all the criteria such as reliability and validity, this means all the items used in this study are capable to measure the particular constructs used in this pilot study and could be used in our next larger scale study. Second, by using the latest approaches and techniques especially by [58], this study empirically proved that the ISC concept is a formative second-order construct that is formed by seven first-order constructs of Procedural Countermeasures (PCM), Risk Management (RM), Security Education, Training and Awareness (SETA), Top Management Commitment (TMC), Monitoring (MON), Information Security Knowledge (ISK) and Information Security Knowledge Sharing (ISKS). This also empirically proved that seven dimensions formulated based on Organizational Culture by [8] and ISC conceptual framework by [21] are relevant and significant in contributing the underlying concept of ISC.

Although the sample population is limited to only one Malaysia public university settings, however, this findings shed some lights on the ISC concept for this particular organization as ISC is depending on organizational type and size [60][61], as well as the national culture [62][63]. Finally, since there is no common agreement on ISC definition and concept especially with regard to factors or dimensions [2], this study provides a new insight in the literature by providing a new holistic concept of ISC based on comprehensive dimensions to fill these gaps. Furthermore, since each dimension is representing an aspect of ISC, the findings from the studies that conceptualize ISC as multidimensional formative second-order construct provide clearer guidelines on aspects of ISC cultivation compared to another type of construct.

VI. LIMITATIONS AND FUTURE WORKS

Although this study provided promising findings on conceptualization and operationalization of the ISC construct, however, this is only a pilot study conducted on a small scale using minimum sample size in order to assess the adequacy of research instruments and selected research methodology before the larger scale of actual study could be conducted. Moreover, although the sample size used in this study met the requirement for data analysis in PLS-SEM as suggested by [38], a bigger sample size is required to convincingly generalize the findings to the population under study. In the next study, we are planning to collect more data from all public universities in Malaysia so that the findings could be convincingly generalized to this population.

VII. CONCLUSION

Experts and scholars recommended cultivating ISC in guiding employee's security behavior in the organizations. However, the conceptualization and operationalization of ISC is still unclear and need to be addressed properly. This study conceptualizes and operationalizes ISC construct that has been developed in our previous works. The findings confirmed that ISC is a multidimensional second-order construct that significantly formed by seven dimensions formulated based on widely accepted concepts of Organizational Culture and ISC.

ACKNOWLEDGEMENT

This research is supported by UMP Post Graduate Research Grant Scheme, RDU160359. The authors fully acknowledged Universiti Malaysia Pahang (UMP) for the approved fund which makes this important research viable and effective.

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 ISBN: 978-1-61208-641-5

Educational Application for K-1 Children using Augmented Reality

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Abstract— **Augmented Reality (AR) has changed the style of education, where students control their way of learning and understanding aspects. AR in education has made learning easier and fun. Interactive applications based on AR technology are evolving rapidly. They unite virtual objects into a real environment, which brings a deeper involvement to the users, increasing the interest towards the application. Many people who encounter AR for the first time have an eye-opening experience, but fail to consider classroom applications as important as they are for teaching purpose. The main motive behind developing the application Vision Augmented Reality in Enhanced Education (VisionAREE) is to introduce AR in education for the children of age 4 to 6 years and to enhance their way of learning. This paper provides an overview of AR and the study of the application VisionAREE including its features, design and implementation phases. Survey results are conducted to aid the utilization of AR for children aged 4 to 6 years old.**

Keywords- Augmented Reality; Education; Android Application; K-1 Classroom.

I. INTRODUCTION

AR is the induction of digital content in real world environment. Users discern physical objects enriched with digital content [1]. AR is considered as one of the latest technology that has spread all over the Information Technology (IT) market successfully and is still progressing to achieve more.

AR technology is being rapidly adopted in educational areas. The researchers discussed that technologies are playing an important role in the improvement of learning and teaching criteria in classrooms in the last few years. One of the emerging technologies is AR which is basically the coverage of virtual information on real world environment and is concerned with the objective to enhance and improve the understandability [2]. VisionAREE is an android application that specifically targets children of ages 4 to 6 years. The application aims to reinforce concepts at younger age with educational subjects and fun activities. VisionAREE has a friendly user interface and does not require any technical knowledge. Our motive is to fill the gap between the young generation and technology in educational area.

This paper includes all the features of the application with their brief description. It also includes the methodology used and the people feedbacks as well as the obtained results. Moreover, some future enhancements are suggested for making the application more versatile.

In this study, the implementation of the application and its learning potential is evaluated. The limitations and difficulties of its development and implementation are discussed. Most people are unfamiliar with new trending technology in Pakistan. The first limitation occurred was limited information and help availability. This limitation was overcome through self-study and research. Another limitation was to explain the audience about AR and then inform about the importance of using such tool in education. The rest of this paper is organized as follows. Section II describes the use of AR in education. Section III describes the methodology which is used to evaluate the effects of AR. Section IV describes the experiments and results. Section V, provides future enhancement of the VisionAREE application. The conclusion closes the article.

II. AUGMENTED REALITY IN EDUCATION

AR is a combination of basically two worlds, i.e., Reality and Virtual Reality. AR is not just limited to old books. Through the 20th century, AR became a vast and strained technology. It is extensively used in many contexts such as advertising and IT. Its actual typical use is through AR games that are much obliging for children. The superimposition of illustrations on real world objects is called AR. AR network is simply based on how a person witness digital information on real objects by simply using smart-phone or any other device that can be worn like goggles.

This technology improves experience of viewing the real world and does not make the person feel distant from it [3].

AR is now considered as one of the fastest growing and newest technologies offering new ways of learning in the era in which the technology has changed the view of education. The use of AR into smart phones has been a growing phenomenon because smartphones are gaining so much popularity all over the world [4].

AR technology, having the capabilities of the induction of digital content in real world environment, opens the door for the development of educational fun applications that connect real and conceptual matter [5]. AR has changed the style of education, where students control their way of learning and understanding aspects. More new methods are being sketched and implemented to overcome the gap between the physical and virtual world.

AR provides different advantages in the educational context [2]:

1) Promoting learning through physical activities.

 ISBN: 978-1-61208-641-5

2) Viewing 3D content from different viewpoints boosts learning.

3) Encouraging students to participate in educational tasks.

4) Yielding information about real world entities concerned with the activities for understanding.

The forms of AR can be described as [6]:

1) Maker based.
2) Object based.
3) Location based.

The devices of AR can be [7]:

1) Mobile devices (smart-phones) enabling to see a 3D model.
2) Personal Computers having a webcam.
3) Glasses and lenses.

There are two main processing architectures in ARS: autonomous and distributed. Autonomous systems carry out all tasks simply in a single device which is generally inexpensive such as mobile phone or computer with webcam. Distributed systems transfer the processing to a server while Mobile AR (MAR) achieved valid significance and acceptance from customers and mobile manufacturing companies [8].

AR has become commonly practical on exclusive smart-phones by 2009. This became possible with the support of advanced features in ubiquitous devices [9]. Figure 1 shows the brands implementing AR and MAR [10]. AR in education can be characterized into 3 main categories of applications, as seen in the article AR in education published in [11].

1) The most deliberated and specialized, best suited for students.

2) Easy and fascinating, created for children to engage them in learning.

3) Best suited for everyone, mainly to improve one's knowledge.

Figure 1. Major Brands Using AR

The article clearly specified that AR in education motivates and engages learners to understand things better and faster. AR helps educators to capture the attention of their students and make them learn in more fascinating way.

The authors of [11] highlighted the main areas where work for pupils has been done. The areas include math, alphabets, animals, insects, fishes, birds and reptiles, life cycle of Monarch butterfly, coloring activities, plants and constructive games. Many educational approaches using AR are better and easier, as the technologies that have made AR possible are stronger than they have been ever before and are sufficiently compactable to deliver AR related experiences to educational places with the help of smart-phones and computers.

By covering the area of school, it was explained how professionals are eager to introduce AR to classroom learning in various subjects and to introduce it into students' guides and augmented books. On the other hand, AR will not be very famous and adopted due to low financial support from the government and less knowledge of AR in educational phase [12].

The researchers explain how feedback can be worthy for teachers as they can provide much insight into children mind. The need for feedback and evaluation sessions with teachers, educational experts and student can pave the way for the development of successful prototypes [5]. The authors of [13] specified that 73% have access to touch-screen devices at their home, whereas in [14] the authors mentioned that 75% of American children under 8 have access to media devices.

A study was done for CPB-PBS in [15] to understand and learn about the AR games. The games are especially being designed for the age group 6-8 years to help them learn in a better way. These games engage children in classroom by providing fascinating activities and developing their interests in technology. Through these activities there is a slight gain in students' enactment. The teachers are also rapidly using these AR games to help students improve their promptness and precision rather than individual teaching tools. The questions to be answered in this context are:

1) Can children learn the targeted math skills in an AR experience?

2) What added value could AR technology bring to class- room settings?

As for results, data was collected by them from the students attending an Out-of-School-Time (OST) program and few of the teachers unaffiliated with the OST program. No remarkable improvement was seen from the result of the students as they faced problems in the usability of AR applications and also the clues were not enough to solve a math problem. Most of the applications lack proper instructions, which might be problematic for children.

According to the results of the above study, WestEd also provided few of the recommendations and conclusions that will surely help in future development of AR technology. Some of the recommendations include that proper hints should be provided according to the given question so that it eases help for children in solving it.

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AR games, designed for learning must contain many levels in it and children self-select the level according to their class or age. The game should also include training materials for teachers as well to help them learn. The use of AR must be, in such a manner, gainful over outdated paper-and-pencil or purely computer-based math instruction.

The above study being conducted by WestEd mainly focuses on two of the AR games i.e. Monster Plus developed by Georgia Institute of Technology and Fetch! Lunch Rush developed by CPB-PBS. Both games run on Apple devices and are marker based.

An entire report in the book [16] I am a little monster, Kingston University has been written on the research of how AR books can become fascinating for children. Parents no longer need videos and games to entertain their children. The entire team for a research trip visited Waterstones (leading book retailer in UK). The purpose was to find out what elements engage children fun reading.

Younger children = touch-feel and audio. Older children = audio, video, pop-ups and games

Parents sometimes find it difficult to create imaginative stories in order to make the book more interesting for children. More than 90% of parents have allowed their kids to play with online games and use educational applications. This means that there would be low barrier while trying AR books. AR books are considered as standalone form of entertainment.

The target audience was children of 2 to 5 years as there is less mental pressure on them.

The top educational applications of AR listed through study and research are:

- One of the most popular applications is FETCH! Lunch Rush, which lets the students learn addition and subtraction in an interesting way [17].
- Quiver, a 3D color AR application which allow students to color and play. They also provide educational discounts to schools [17].
- Matching Objects and words (MOW), words from different languages are taught through this application [18].
- Zoo Burst, an AR application which changed a simple story telling to a different world of 3D characters [19].
- Elements4D, an AR application which changed a simple subject chemistry into an interesting world of animation [19].

In order to engage in more cognitive operations, children should operate and read by themselves rather than have their parents do it for them as it may not be constructive. Parents should refrain from controlling and narrating to their children so that their children can gain higher level of understanding and perception during the process [20].

A. *Features of VisionAREE*

VisionAREE distinct feature from existing educational AR applications is that it just not only includes exercises but it also provides entertainment in the form of coloring book and 3D animations. It brings objects to life and aims to grasp children attention. The features include:

- Mathematics, which includes addition, subtraction, multiplication, even and odd numbers.
- English, which includes grammar (vowels, nouns, verbs), easy sentences completion, poems with 3D animation.
- General Knowledge (Info Bee), which includes infor- mative 3D animation that will help them learn about seasons, flags, plants.
- Coloring Book Activity (Color Me), which includes coloring on paper that will make the 3D animated character being colored the same, comparison with original picture.
- Know Me: Real World environment object recognition, specifically the class room objects.
- Text-to-Speech, playback audio and Demo.
- Evaluation Quiz and Progress Report generation.

III. METHODOLOGY

The whole research has been done by conducting surveys, analyzing the results and reading research papers. During the development process, all four group members of the project tested the application. Around 40 users used and evaluated the final results of the application and tested it in all respects. Evaluation on the basis of comparison with other traditional methods was also performed which resulted in the favor of usage of AR application. By using survey forms, we tried to observe how parents think about the usage of smartphones for their children and whether they are aware of AR technology. We assured to cover and include all those types of questions that can conclude the views and aspects of people for the project. Throughout the development of the project VisionAREE, feedbacks were taken from various people we came across at home, institutes, workplace, exhibitions and competitions. This led to the successful designing and development. Reviews from users were taken under consideration and the application was reshaped each and every time for better UX/UI, so that the main purpose of the application is met. The idea was supported and appreciated. The project VisionAREE was also demonstrated in Montessori Complex High School, Karachi where a class of 40 first grade students was present. The application was not included in a specific course environment. Moreover, it was also presented in exhibitions and competitions several times where it earned top positions.

A. *Implementation Phase*

VisionAREE is using Vuforia SDK for AR functionality and the marker based approach. The markers are referred to as the image-targets. The user has nothing to do with the knowledge of the image-target but with the cards, pictures and stickers that has the answers understandable by them. The user hovers the phone on cards, pictures or stickers and sees 3D content augmented on them. The 3D content provides more information and insight. The user taps on the 3D model to answer. Figure 2 shows the Winter Card and Figure 3 shows its

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corresponding AR model for the visualization of Winter Season. Similarly, Figures 4 to Figure 7 show other implemented 3D models.

Figure 2. Winter Card

Figure 3. Animated 3D model

The user is provided with demo videos, definitions and hints to learn more. VisionAREE also has the text-to-speech feature that opens the door for children to understand more and answer efficiently. The application has two modes to select between, quiz mode and demo mode. Demo mode beings very friendly and helpful with demo videos and other help available while quiz mode has more test-like interface where there is timer and scores are calculated and stored. The modes provide the child with the flexibility to learn and to test. The content of the application is unchangeable, so it is not possible for teachers or anyone to add or update content.

B. Testing Phase

The implementation was tested at each and every stage of the module both during the development and then on the android phone by building and testing. Another important thing taken into consideration is that the 3D model is stable enough on the image-target. This thing is achieved by testing and editing the images and checking their ratings.

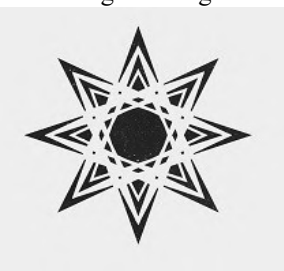

Figure 4. Unstable

Figure 5. Stable

The image-targets are then placed on the cards that are designed and are easily understandable by the users.

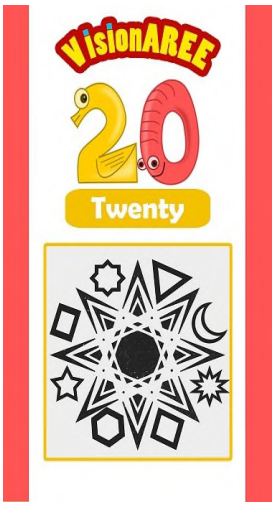

Figure 6. Math Card

Figure 7. 3D models on card

Questions should be appearing according to their category.

Figure 8. Question for Noun

Testing has been done for the availability of demo in Demo mode. Figure 8 to Figure 10 show the demo version of the application, 3D models and animations on their respective image-targets in proper size, color being mirrored at run-time on the model in Color Me module.

 ISBN: 978-1-61208-641-5

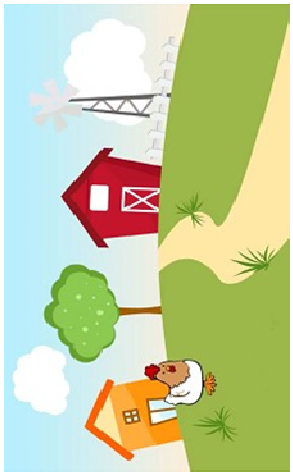

Figure 9. Demo Video in Math

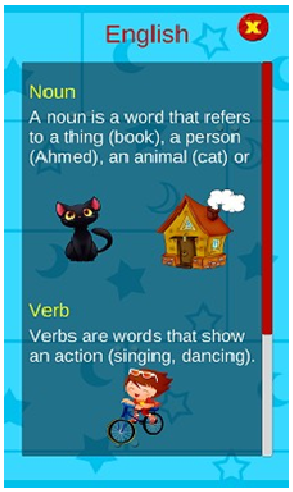

Figure 10. Demo in English

Figure 11 shows the colored model.

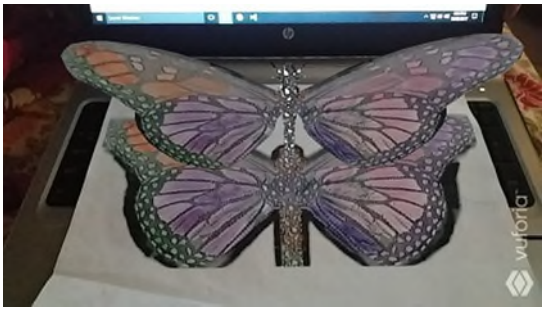

Figure 11. Colored Model

Text-To-Speech activation for better understandability. Scores being properly calculated and stored in memory. The same has been shown in Figure 12.

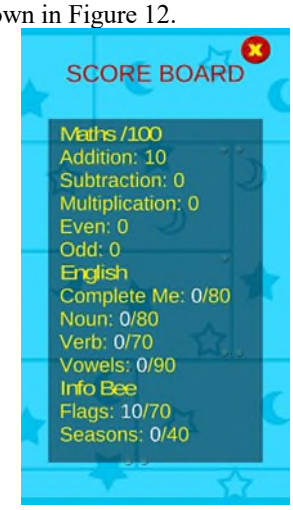

Figure 12. Scores

The other thing taken under consideration is the efficiency and the response time of the application. In interface is designed in accordance with the age level.

C. *Evaluation Phase*

The evaluation of the project is determined by the completion of each of the sub module specified. Each sub module for example in math, a logical question generation followed by user input and performing system calculations and verifying the answer and also keeping track on the user progress should all work properly. Figure 13 shows the evaluation of the application.

Figure 13. Evaluation

IV. EXPERIMENTS AND RESULTS

According to the survey conducted, 46.2% of the parents in Pakistan do not support the idea that children should use smartphones. 64% of children do not have their own smartphone but 77% of parents do allow them to play with it. The thing which is worth noting is that the same percentage of parents that is 77% said that they have installed educational applications for their children and 74.4% let their children use a smartphone for 1-2hr per day while 20.5% reported 3-4hr and the rest, 5-6hr. Upon asking if the parents have prior knowledge about AR the result was slightly more in favor with the percentage of only 51.3%, but when asked if they have ever used the famous AR applications by name, particularly Snapchat and Pokemon GO, 64% responded saying yes. This shows that many parents are using AR applications but are not familiar with the term. 61.5% parents rejected the view that smart-phones are a waste of time. There was not a single negative response to the question, Do you think smart-phones can be used for educational purpose, with 87.2% saying yes and 12.8% saying maybe. 82.1% that is a significant majority supported the idea that educational application should be implemented in schools and the same percentage of parents that is 82.1% responded that it will not be hard for them to teach their children through smartphones.

 ISBN: 978-1-61208-641-5

77% of the parents reported that educational applications will develop interest in children. On visiting Montessori Complex High school, Karachi we demonstrated VisionAREE to first grade students. Prior to that, we had talked to the school representative who had concerns about the usage of smartphones by children. On demonstrating and explaining the project and idea to the representative we were able to change his thoughts and were appreciated. The project was loved by the children and tremendous amount of interest was shown by them. Every child eagerly and excitedly participated in the activity. However, we noticed a traditional learning way of students where it was hard for them to understand the question in a way other than they are familiar with. Reading out the question as 4 multiply by 4 they were getting confused but after saying "4 4 za" they answered promptly. In a class of 40 first grade students, approximately 80% said that they use smartphones and tablets at home. 62% said that they use educational applications.

Some significant feedbacks that are implemented and must be highlighted are:

- Adding the feature Know Me so that the children can learn about classroom objects.
- Adding a demo picture in Color Me so that the child can compare the colored picture with it.
- Adding timer in quiz mode.
- Not to let the question change unless it is answered correctly in demo mode.
- Other correction related to UX and UI for better accessibility.
- Adding text to speech feature for better understandability.
- Resetting the scores in scoreboard if another user wants to play on the same device.
- Demonstration videos and manual are made easily available.

V. FUTURE ENHANCEMENT

VisionAREE's specialty is that it has flexibility with respect to enhancements. It provides enough space in which it can be easily enhanced in future.

Extending age limit

Enhancements can be done by upgrading the age group and subjects. As the application is designed according to the level of 4 to 6 years, it can be made for higher grade students.

As a desktop application

The application although uses smart-phones but can be deployed on computers and can be used as a desktop application. Therefore, the students will be able to use this application according to their choice and feasibility. As many parents do not have smart-phones but have computers in their house, so in this way it will be helpful for them.

Modification by adding more subjects

The application targets the pre-primary level of education. Modification can be done for almost any subject so that, students can gain more interactivity with this application.

Building for IOS

The application is currently developed for android devices and can be developed for IOS as a future enhancement so that the non-android users can also use the application.

VI. CONCLUSION

Technology is endlessly evolving, and the development of new applications sometimes acts as a touchstone to the arrival of a completely new technological paradigm. It is to conclude that our application VisionAREE is mainly designed for the purpose of education using the AR technology. It aims to help students in ways that can strengthen their concepts and boost their skills, making complex information easier to understand and fun. Breaking the barriers of traditional learning is one of the main focus of the application. The apparition behind VisionAREE is of great significance for the betterment of education sector in Pakistan.

ACKNOWLEDGMENT

Our deepest gratitude to our internal advisor Dr. Shakil Ahmed (Chairman, CED, SED). We acknowledge his cooperation and endeavor to assist us for the completion of our project. We are highly indebted to the Final Year Project Committee of Computer Engineering department, Sir Syed University of Engineering and Technology for their guidance, constant supervision and for their support to make our project successful.

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 ISBN: 978-1-61208-641-5

Detecting Counterfeit Bills and Their Forgery Devices using CNN-based Deep Learning

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***Abstract*—Counterfeit bills are easy to forge due to the advances in scanning and printing technologies. Individuals are less likely to find counterfeit bills. This paper proposes a deep learning-based algorithm to detect counterfeit bills and their forgery devices. The proposed algorithm has adopted a convolutional neural network model composed of 2 convolutional layers and 2 fully connected layers. In the convolutional layers, rectified linear unit and max-pooling are applied. In the fully connected layers, drop out is applied. To show the performance of the algorithm, experiments are performed using original bills and counterfeit bills forged with different manufacturers' printers. Nearly 100% detection accuracy has been achieved.**

Keywords-counterfeit bill detection; forgery device detection; deep learning; convolutional neural network.

I. INTRODUCTION

High performance scanning and printing devices can be accessed at low cost with the advances of IT (Information Technology). In addition, high quality image processing software has been developed. As a result, the general public can easily process complex tasks. However, novices can use these advanced technologies to create illegal products.

Credibility of currency is important in an economic society. Loss of currency credibility damages not only personal property but it also harms national creditworthiness. Recently, crimes forging counterfeit bills with high performance devices and high quality software are rapidly increasing.

Although various anti-counterfeiting technologies are applied to prevent counterfeiting such as magnetic stripe line, ultra violet watermark, and hologram pattern, counterfeit bill detectors require too high a cost and individuals are less likely to find counterfeit bills because too many bills are circulating.

To solve this problem, many counterfeit bill detection researches have been performed using tools such as ultra violet features, electro-magnetic features, and printing noise features. This paper focuses on research that uses printing noise features, where human beings have defined the features to discriminate between original bills and counterfeit bills. Then, these features were applied to the classifier. However, human beings have a limitation to define sophisticated features to discriminate between original bills and counterfeit bills.

This paper proposes a deep learning-based algorithm to detect counterfeit bills and their forgery devices. Since deep learning algorithms are not limited to human cognitive abilities, differently from human beings, the proposed algorithm can extract the sophisticated features by itself and hence robustly discriminate between original bills and counterfeit bills. The proposed algorithm has adopted a Convolution Neural Network (CNN) model, which is mainly used in image processing fields [1]. The model is composed of 2 convolutional layers having Rectified Linear Unit (ReLU) as an activation function and max-pooling and 2 fully connected layers having a drop-out function to prevent overfitting. Finally, a SoftMax function is used to rectify the results. Using original bills and counterfeit bills that are forged with 3 different color laser printers, experiments are performed. Nearly 100% accuracy in detecting counterfeit bills and their forgery devices has been achieved.

The paper is organized as follows. Section II reviews related works. The proposed algorithm is explained in Section III. Section IV shows experimental results and Section V concludes.

II. RELATED WORKS

To detect counterfeit bills, a lot of research is underway and its performance depends on how to extract accurately the unique characteristics of counterfeit bills that are different from the original bills. Among anti-counterfeiting technologies, the features used in previous studied algorithms are Ultra Violet (UV) features, electro-magnetic features, and printing noise features.

A. UV Features

UV features are easier to detect than other features. Chae et al. used the fact that UV information was only part of the bill [2]. Their algorithm improved accuracy and computation speed over conventional UV-based discrimination methods. After dividing the UV information extracted from the bill into 3x4 blocks, the difference from original bills was calculated to detect counterfeit bills. The detection rate of counterfeit bills was 100% and the accuracy of original bills was 99.3%.

Lee et al. proposed a speed optimized method to automatically detect UV information without using a conventional passive UV detection method [3]. The images obtained by UV illumination were separated by a Gaussian mixture model and Split-and-Merge EM (SMEM) algorithm.

 ISBN: 978-1-61208-641-5

Then, the size and weight of the covariance vector were considered to judge whether it was forged or not.

B. Electrical Features

Researches using electro-magnetic features of a printing material are also progressing steadily. Kang et al. proposed a counterfeit bill detection system by contacting a fiber optic sensor with a specific part of the bills [4]. In the bill, the area representing the amount of the bill was scanned through the optical fiber and the voltage measurement was used to make judgement. As a result, 100% accuracy was achieved in the test with Korean $50 bills.

C. Printing Noise Features

The noise features of printing devices can be used to detect counterfeit bills, and the algorithm proposed in this paper falls into this category. Ji et al. extracted non-local feature values and applied a support vector machine classifier to discriminate counterfeit bills [5]. Also, they identified printing devices to forge them. After extracting the noise factors of printing devices using a non-local averaging algorithm, feature values were extracted by calculating the Gray level co-occurrence matrix. Counterfeit bill detection accuracy was about 94% and their forged device detection accuracy was about 93%.

Baek et al. proposed an algorithm using low resolution multispectral images, where human readable features such as optically variable ink and machine readable features by multi-channel IR (Infra Red) hardware sensors are combined to discriminate counterfeit bills from original bills [6]. They achieved 100% detection accuracy for counterfeit bills with 99.8% classification accuracy.

There are other studies to detect printing devices. Lee et al. used a Wiener filter to extract the noise feature of printing devices, which was useful for removing abnormal noise [7]. Since printers converted the RGB (Red, Green, Blue) channels of images to the CMYK (Cyan, Magenta, Yellow, Black) channels for printing, the scanned image having the RGB channels was transformed into the CMYK channels. Then, the printing noise was extracted by calculating the difference between the image and its Wiener-filtered image and was used as the feature.

Choi et al. and Baek et al. used high-frequency components that were extracted by discrete wavelet transform as the printing noise feature [8] [9].

Ryu et al. studied a printing device detection algorithm considering that color laser printers had a unique pattern for CMYK printing [10]. The directional information of the linear characteristics existing in the printing pattern was extracted using Hough transform and was used as the feature.

Against mistreated Mexican bills, not counterfeit bills, Garcia-Lamont et al. proposed a classification method, where their color and local binary patterns from texture features are used [11].

However, in these algorithms, there are disadvantages that human beings must design a method to extract features and there are limitations in designing the sophisticated way to extract features for distinguishing between original bills and counterfeit bills.

III. Proposed CNN-based Detection Algorithm

In order to detect counterfeit bills and their forgery devices, a deep learning-based algorithm based on CNN has been proposed, which consists of two steps: training and testing. Figure 1 shows the overall process of the algorithm. Using training data, the proposed model is trained and the accuracy is evaluated by comparing with the label of the training data. Then, the weights and biases of the model are updated via error back propagation with reference to the accuracy. After learning a certain number of times, testing data are applied to the model and detection results are analyzed to calculate the accuracy.

Deep learning is a neural network that has deeper layer than existing artificial neural networks. According to recent studies, the CNN model among various deep learning models is suitable for image processing applications and can extract sophisticated features to achieve high performance without human intervention [1].

Therefore, the proposed algorithm to detect counterfeit bills and their forgery device is designed using this CNN model. In general, the CNN model consists of an input layer, a convolutional layer, a fully connected layer, and an output layer.

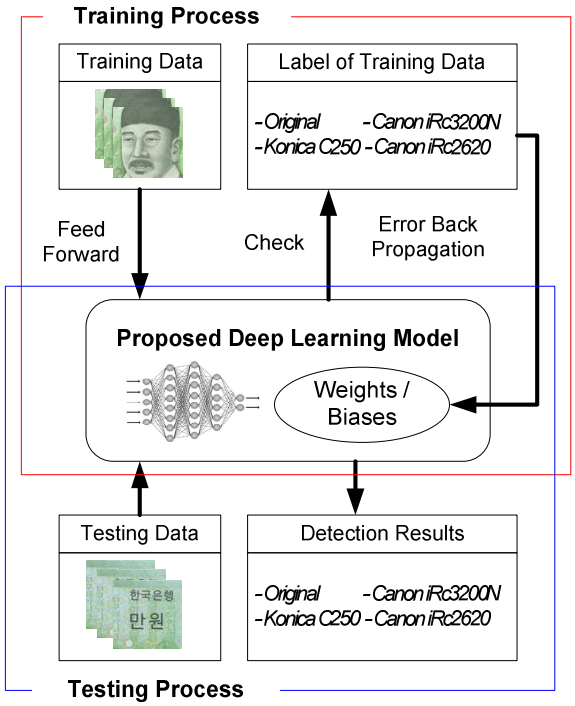

Figure 1. Counterfeit bills and their forgery device detection process

Generally, the convolutional layer includes a convolution operation, a pooling operation, and an activation function. The convolution operation can extract features considering the values of local pixels by a matrix operation of image and filter. The pooling operation leaves only pixel values that satisfy certain rules among the pixels in a specific area. This can reduce the size of the input data and improve the processing speed. However, it can lose important pixel

values that can contribute to identify counterfeit bills. When linear results are used, normal learning is difficult due to the problem of vanishing gradients in the back propagation process. Therefore, an activation function is used to nonlinearly change the results of the previous layer.

The fully connected layer is the most basic component of an artificial neural network. The data from the previous layer are used as input nodes one by one and fully connected to the output nodes. Overfitting is a situation in which too much data are learned for a particular dataset and hence fails to provide adequate results for additional data. To prevent overfitting, drop-out is a normalization technique, which drops random nodes of fully connected layer nodes during the learning process [12]. Differently from our previous research, which just focused on differentiating between original bills and counterfeit bills [13], the output layer is composed of 4 nodes to identify forgery devices and parameters are tuned to improve the performance.

The output values of the fully connected layer can be varied in range. To rectify the values, a SoftMax function is applied in the output layer.

The detail of the proposed CNN-based model is depicted in Figure 2, which consists of 4 layers: an input layer, a convolutional layer, a fully connected layer, and an output layer.

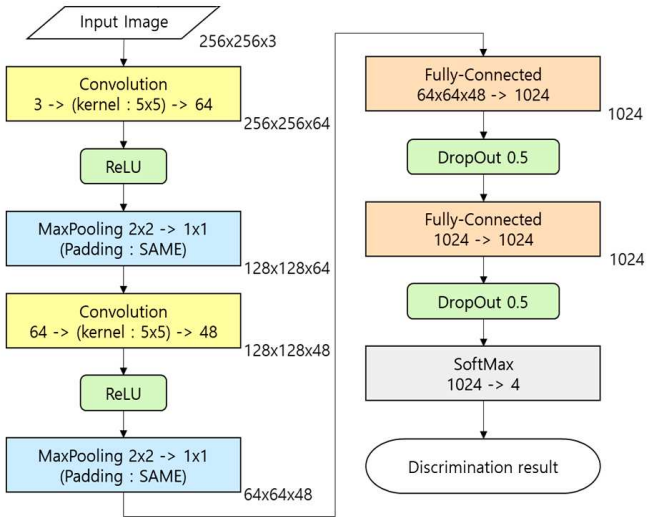

Figure 2. Details of the proposed CNN-based model

The input layer and the output layer are matched to an input image and discrimination result, respectively. The initial values of weights and biases were adjusted.

The 1st convolutional layer receives 256x256 color images having RGB channels and outputs 64 feature maps by convolving a 5x5 kernel. ReLU is used as an activation function and the 256x256 size of feature maps is reduced to the 128x128 size of feature maps through max-pooling with stride 2. The 2nd convolutional layer receives 64 feature maps as an input and outputs 48 feature maps. The same activation function is used as the first layer and max-pooling with stride 2 reduces the 128x128 size of feature maps to the 64x64 size of feature maps.

256x256 color images having RGB channels become 48 feature maps having a 64x64 size through 2 convolutional layers. Then, these feature maps are rearranged into a one-dimensional array with 64x64x48 values.

Through the 1st fully connected layer, these values are output to 1024 nodes, where a drop-out processing of 0.5 rate is applied to prevent overfitting. Also, through the 2nd fully connected layer, the discrimination result is acquired after rectifying the value with the SoftMax function.

IV. Experimental Results

For the experiment, original bills are scanned to make original bill images. Then, counterfeit bills are created by printing these original bill images and scanned again to get the counterfeit bill images. As printers for counterfeiting, we used Konica C250, Canon iRc3200N, and Canon iRC2620 color laser printers.

Due to the memory limitation of deep learning hardware, it is impossible to use the scanned bill images directly. Therefore, scanned bill images are randomly cropped with 100 images of 256x256 size. Since the data ratio of the original bill images and the counterfeit bill images is 1:3, up-sampling is performed to 300 original bill images.

The entire data consists of 10,800 (36x300) original bills and 10,800 (36x100x3 printers) counterfeit bills. The ratio of the training data to the testing data is 8:2, i.e., 8,640 and 2,160, respectively. Figure 3 shows original bill images and counterfeit bill images generated by each printing device.

Original Bills	Counterfeit Bills		
	C250 (Konica)	iRc3200N (Canon)	iRC2620 (Canon)
			
			

Figure 3. Original bill images and counterfeit bill images with each device

A. Detection Accuracy

The detection accuracy of original bills, counterfeit bills and their forgery device is analyzed to show the performance of the proposed algorithm. The results are depicted in Figure 4 and summarized in Table I. In Figure 4, a horizontal axis represents the number of epochs and a vertical axis indicates the detection accuracy. In Table I, the last column (All) is the average of detection accuracy for 3 printers.

As shown in the results, the detection accuracy increases with the increase of epochs. After 25 epochs, the detection rate of original bills and counterfeit bills is 100%. Also, the detection of their forgery device is 100%. It means that the proposed algorithm using CNN-based deep learning can

 ISBN: 978-1-61208-641-5

extract the sophisticated features for discriminating original bills and counterfeit bills. Also, it can discriminate the differences among their forgery devices.

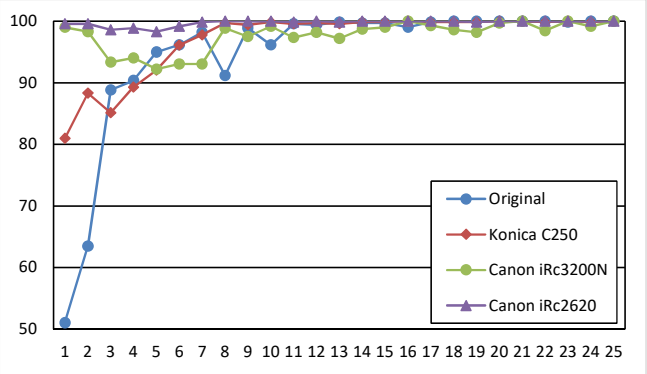

Figure 4. Counterfeit bill forgery device detection accuracy

TABLE I. DETECTION ACCURACY OF COUNTERFEIT BILLS AND THEIR FORGERY DEVICE (PER EPOCH)

Epoch	Original	Counterfeit Bills and Forgery Device			
		C250 (Konica)	iRc3200N (Canon)	iRc2620 (Canon)	All
1	51.02	80.97	99.03	99.58	93.19
2	63.47	88.33	98.33	99.58	95.41
3	88.84	85.14	93.33	98.61	92.36
4	90.37	89.31	94.03	98.89	94.08
5	95.00	92.08	92.22	98.33	94.21
6	96.16	96.11	93.06	99.17	96.11
7	98.19	97.78	93.06	99.86	96.90
8	91.20	99.72	98.89	100.00	99.54
9	98.89	99.44	97.50	100.00	98.98
10	96.16	99.86	99.17	100.00	99.68
11	99.58	99.58	97.36	99.86	98.93
12	99.44	99.72	98.19	100.00	99.30
13	99.86	99.58	97.22	99.86	98.89
14	99.72	99.86	98.75	100.00	99.54
15	99.72	99.86	99.03	100.00	99.63
16	99.07	100.00	100.00	100.00	100.00
17	99.86	99.86	99.31	100.00	99.72
18	100.00	99.86	98.61	100.00	99.49
19	100.00	99.86	98.19	99.86	99.30
20	100.00	100.00	99.72	100.00	99.91
21	100.00	100.00	100.00	100.00	100.00
22	100.00	99.86	98.47	100.00	99.44
23	99.86	100.00	100.00	100.00	100.00
24	100.00	99.86	99.17	100.00	99.68
25	100.00	100.00	100.00	100.00	100.00

V. CONCLUSION

As scanning and printing devices are improved and costs are reduced, counterfeit bills are made easier than ever. As a result, counterfeit bills have been circulated in various ways, and anti-counterfeiting technologies have been studied to prevent counterfeiting crimes.

In this paper, we proposed a CNN-based deep learning algorithm that could detect counterfeit bills and their forgery devices. Also, we performed intensive experiments to show the outstanding performance. The proposed algorithm could achieve 100% accuracy in discriminating between original bills and counterfeit bills. Also, it could identify their forgery devices with 100% accuracy.

In the experiments, contaminated bills commonly found in practice are not considered. Therefore, it is necessary to perform additional studies for commonly used damaged and contaminated bills. Also, we consider increasing the depth of the model or including pre-processing filters. Therefore, there are many opportunities to research.

ACKNOWLEDGMENT

This work was partly supported by the research fund of National Security Research (2018-069).

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 ISBN: 978-1-61208-641-5

Using Online Manifold Learning for Color Image Quality Assessment

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***Abstract*—The structure of the low-dimensional characteristics of images is manifold, which is precisely what the human visual system perceives. With this inspiration, a new Image Quality Assessment (IQA) metric called Online Manifold Learning based Quality (OMLQ) is proposed for color IQA in this paper. Online manifold learning is employed to construct a feature extraction matrix, which is used to obtain low-dimensional manifold vectors. In addition, visually important regions are detected to mimic the properties of the visual perception. The new IQA score is defined as the similarity of feature vectors between reference image and the corresponding distorted one. Extensive experiments performed on three publicly available benchmark databases demonstrate that the proposed IQA index OMLQ works better in terms of prediction accuracy than the other state-of-the-art indices.**

Keywords-color image quality assessment; visual saliency; human visual system; manifold learning.

I. INTRODUCTION

The quantitative evaluation of an image's perceptual quality is one of the most fundamental yet challenging problems in image processing system and vision research, confirmed by the idiom, "A picture is worth a thousand words" [1]. Objective image quality assessment is capable of approximating subjective opinion of an average human observer by employing an efficient computational model, which is suitable for different image content, different distortion types and different degree of distortion [2]. As conventional metrics, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are widely accepted due to their computational efficiency and definite physical meaning. However, MSE or PSNR do not correlate well with human beings' subjective scores with a variety of image content and distortion types involved since they do not consider the properties of Human Visual System (HVS) and just measure the pixel difference between reference and distorted image.

Structural Similarity (SSIM) [3] index based on the hypotheses that HVS is highly adapted for extracting structural information in images, can be considered a milestone of the development of Image Quality Assessment (IQA) models, it can provide a good prediction of the perceived quality score. In the following years, many SSIM extensions are proposed, such as Multi-Scale SSIM (MS-SSIM) [4], Complex Wavelet SSIM (CW-SSIM) [5], information weighted SSIM (IW-SSIM) [6], and so on. The research in [7] proposed a wavelet-based Visual Signal-to-Noise Ratio (VSNR) metric, which operates via a two-stage approach in the wavelet domain based on near-threshold and supra-threshold properties of human vision. Except for structural approaches, Sheikh et al. proposed the Visual Information Fidelity (VIF) index [8], which was an extension of its former version, namely the Information Fidelity Criterion (IFC) index [9]. VIF tries to quantify the amount of information shared between the reference image and the corresponding distorted one. Larson et al. asserted that the HVS performs different strategies for high-quality image and low-quality image. Inspired by this, they proposed a Most Apparent Distortion (MAD) model which shows remarkable and robust result [10]. In addition, a different IQA approach, based on Sparse Representation (SPARQ) index [2], is proposed for gray image. Most commonly used algorithms are just designed for gray image, but in RGB image graying process, there is part of information lost, resulting in inaccurate evaluation results.

For visual perception phenomenon, studies have shown that manifold is the basis of perception [11]. There exists massive redundancy in the high-dimensional digital image data, it is essential to reduce the dimension but still maintain essence of structure. Given a set of high-dimensional data points, manifold learning aims at discovering the nonlinear geometric properties embedded in high-dimensional data space of low-dimensional manifolds, which reflects the intrinsic nature of things. Deng et al. introduced a novel subspace learning algorithm, called Orthogonal Locality Preserving Projection (OLPP) [12], which can find the manifold structure of image. We can apply OLPP algorithm to the given image patches, mapping it to a low- dimensional manifold, so the feature extraction will be achieved.

Motivated by above consideration, this paper presents a novel IQA model for color image, called Online Manifold Learning based Quality (OMLQ). We use visual saliency (VS) model to strike a maximum combined saliency map and a maximum absolute difference map from RGB color space to detect visually important regions. OMLQ relates perceived quality of an image with the fidelity to the reference image in the form of manifold features that are extracted in the detected salient regions by a feature detector, i.e. feature extraction matrix obtained by online OLPP. Finally, the manifold features are used to predict an objective value.

 ISBN: 978-1-61208-641-5

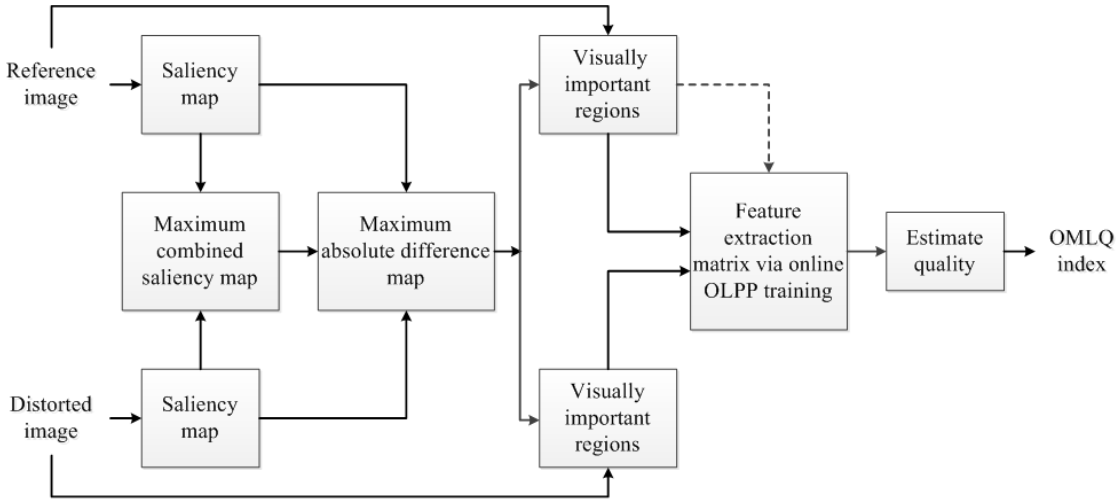

Figure 1. Illustration for the computational process of the proposed model OMLQ

II. THE PROPOSED APPROACH

Because HVS has the ability to capture nonlinear manifold structure, we propose a metric based on online manifold learning for color image quality assessment. The procedures to compute OMLQ are illustrated in Figure 1.

It is acknowledged that not every pixel in an image receives the same level of visual importance. The relationship between VS and IQA has been investigated by some researchers and it is broadly recognized that incorporating VS information appropriately can benefit IQA metrics. In this work, we experiment with the VS model in [13] to detect the visually important regions.

1) Let M^r and M^d denote the saliency maps pertaining to reference image I^r and distorted image I^d, computed by VS model mentioned above. A maximum combined saliency map $M^{\max}$ with the same size of M^r and M^d is created with $\max(M^r, M^d)$. It is well known that an average observer perceives the world in color instead of black and white, so we directly deal with the RGB image. Before the computation, the I^r, I^r, M^r, M^d, and $M^{\max}$ should be first divided into non- overlapping 8×8 patches and then each of them is vectorized and arranged by scanning the numerical values in columns, which forms the matrices: reference image patch matrix $\mathbf{X}^r$, distorted image patch matrix $\mathbf{X}^d$, reference saliency patch matrix $\mathbf{S}^r$, distorted saliency patch matrix $\mathbf{S}^d$, and the maximum combined saliency patch matrix $\mathbf{S}^{\max}$, respectively. Since a color image has three channels, the length of $\mathbf{X}^r$ and $\mathbf{X}^d$ is 8×8×3=192. The length of $\mathbf{S}^r$, $\mathbf{S}^d$, and $\mathbf{S}^{\max}$ is 8×8=64.

2) Let $\mathbf{S}_j^{\max}$ denote the value of the *j*th column in the maximum combined saliency patch matrix $\mathbf{S}^{\max}$, then the saliency of the *j*th patch of $M^{\max}$ is expressed by

$$d_j = \sum_{i=1}^{N} S_{ij}^{\max} \quad (1)$$

where N denotes the number of pixels in a patch, $\mathbf{S}_{ij}^{\max}$ denotes the value of the ith row and jth column in $\mathbf{S}^{\max}$. Suppose $t_1 = \lambda_1 \cdot k$, where λ_1 to the range (0,1] indicates the scale factor of the selected maximum combined saliency patch, t_1 represents the number of selected salient patches. and k denotes the number of patches extracted from each image. We select the first largest t_1 saliency value d_j corresponding to the reference image patch matrix $\mathbf{X}^{r*}$ and the distorted patch matrix $\mathbf{X}^{d*}$. Similarly we can get the corresponding reference saliency patch matrix $\mathbf{S}^{r*}$ and the distorted saliency patch matrix $\mathbf{S}^{d*}$.

Here, based on $\mathbf{S}^{r*}$ and $\mathbf{S}^{d*}$, the difference between a pair of vectors is measured by the mean absolute error, then the absolute difference value e_j is defined as

$$e_j = \frac{1}{n}\sum_{i=1}^{n} |S_{ij}^{r*} - S_{ij}^{d*}|, \quad j = 1,\mathrm{L}\ ,t_1 \quad (2)$$

Let $t_2 = \lambda_2 \cdot t_1$, where λ_2 is the scale factor of the selected patch and t_2 denotes the number of selected maximum absolute difference patches. We take the first t_2 largest e_j corresponding $\mathbf{X}^{r*}$ and $\mathbf{X}^{d*}$ as the final visually important regions, denoted by $\mathbf{Y}^r$ and $\mathbf{Y}^d$. The goal of feature extraction is the acquisition of a feature detector, which is applied to evaluate the image quality. Many researchers usually receive a learner through off-line mode, which requires a lot of training samples and has significant limitations in real-time applications. Therefore, we apply online learning adaptively updating feature detector. First, each sample vector is centered by subtracting the mean pixel value of each patch. All the sample vectors construct a matrix Y as online OLPP learning input. Next, following the intuition that the image

 ISBN: 978-1-61208-641-5

data may be generated by sampling a probability distribution that has support on or near a submanifold of ambient space, we apply OLPP algorithm to project the sample vectors into a subspace to obtain manifold features. The procedure of online OLPP learning is stated by.

1) **PCA Projection:** By throwing away dispensable components, we preserve the maximum amount of the sample vectors and discard redundant information after the matrix Y is projected into the PCA subspace. PCA can be done by eigenvalue decomposition of a covariance matrix. After the decomposition, let $\boldsymbol{\psi} = diag(\psi_1,\mathrm{L}\ ,\psi_M)$ and $\mathbf{E} = diag(e_1,\mathrm{L}\ ,e_M)$ indicate the M largest eigenvalues and the corresponding eigenvectors for the covariance matrix. In our work, M is fixed at 8. This means the dimension of each whitened vector will be reduced from 192 to M=8. The whitened matrix, **W**, is given by

$$\mathbf{W} = \boldsymbol{\Psi}^{-1/2} \times \mathbf{E}^{\mathrm{T}} \tag{3}$$

Eventually, sample data Y can be whitened into $\mathbf{Y}^w$ by the following implementation

$$\mathbf{Y}^{\mathrm{w}} = \mathbf{W} \times \mathbf{Y} \tag{4}$$

2) **Constructing the Adjacency Graph:** Let G represent a graph with m nodes. The a-th node corresponds to whitened sample data y_a^w. We connect them when node a and node b are adjacent, i.e., y_a^w is among k nearest neighbors of y_b^w.

3) **Choosing the Weights:** If node a and b are connected, set $S_{ab} = e^{-\left\|y_a^w - y_b^w\right\|^2}$, otherwise, set $S_{ab} = 0$. The weight matrix S of graph G exactly explains the local structure of image manifold.

4) **Computing the Orthogonal Basis Function:** We define Φ as a diagonal matrix, which is expressed by $\Phi_{aa} = \sum_{a=1}^{N} S_{ab}$. We also define Laplacian matrix L, i.e. $\mathbf{L} = \boldsymbol{\Phi} - \mathbf{S}$. Let $\{\mathbf{p}_1,\mathrm{L}\ ,\mathbf{p}_n\}$ be the orthogonal basis vectors, then

$$\mathbf{P}^{(n-1)} = [\mathbf{p}_1,\mathrm{L}\ ,\mathbf{p}_{n-1}] \tag{5}$$

$$Q^{(n-1)} = [\mathbf{P}^{(n-1)}]^T (\mathbf{Y}^w \boldsymbol{\Phi} \mathbf{Y}^{wT})^{-1} \mathbf{P}^{(n-1)} \tag{6}$$

The orthogonal basis vectors are computed as follows.

- Compute $\mathbf{p}_1$ by the eigenvector corresponding to the smallest eigenvalue of $(\bar{\mathbf{Y}}^w \boldsymbol{\Phi} \bar{\mathbf{Y}}^{wT})^{-1} \bar{\mathbf{Y}}^w \mathbf{L} \bar{\mathbf{Y}}^{wT}$.
- Compute $\mathbf{p}_n$ by the eigenvector corresponding to the smallest eigenvalue of $\mathbf{M}^{(n)}$

$$\mathbf{M}^{(n)} = \{\mathbf{I} - (\mathbf{Y}^w \boldsymbol{\Phi} \mathbf{Y}^{wT})^{-1} \mathbf{P}^{(n-1)} [\mathbf{Q}^{(n-1)}]^{-1} [\mathbf{P}^{(n-1)}]^T\} \cdot (\mathbf{Y}^w \boldsymbol{\Phi} \mathbf{Y}^{wT})^{-1} \mathbf{Y}^w \mathbf{L} \mathbf{Y}^{wT}$$

5) **Feature Extraction Matrix by OLPP Embedding:** Suppose the best projection matrix $\mathbf{J}_{OLPP} = [\mathbf{p}_1,...,\mathbf{p}_l]$. After the learning process, the feature is transformed from the whitened space to original space by

$$\mathbf{D} = \mathbf{W} \times \mathbf{J}_{OLPP} \tag{7}$$

where D is the feature extraction matrix through online OLPP learning, which is used to extract image features that capture intrinsic manifold structure in an image.

After the online OLPP learning step, the manifold feature vectors, $\mathbf{u}_i$ and $\mathbf{v}_i$, can be extracted by a multiplication operation.

$$\mathbf{u}_i = \mathbf{D} \times \mathbf{y}_i^r, \mathbf{v}_i = \mathbf{D} \times \mathbf{y}_i^d \tag{8}$$

Since the size of D is 8×192, the length of $\mathbf{u}i$ and $\mathbf{v}i$ is 8. For simplicity, we use a vector pair to represent the features of a reference patch together with its distorted patch. Therefore, all of the feature vectors of $\mathbf{Y}^r$ and $\mathbf{Y}^d$ are concatenated to form two matrices, U and V, respectively.

Finally, we defined perceived quality score as the feature similarity by

$$Score = \frac{1}{K \bullet M} \sum_{i=1}^{K} \sum_{j=1}^{M} \frac{2\mathrm{U}_{ij}\mathrm{V}_{ij} + C}{(\mathrm{U}_{ij})^2 + (\mathrm{V}_{ij})^2 + C} \tag{9}$$

where K denotes the number of image patches in visually important region, i.e., the number of manifold features is reserved, M represents the dimension of manifold features. C is a positive constant that supplies numerical stability.

TABLE I. PERFORMANCE COMPARISON UNDER DIFFERENT TYPES OF DISTORTION ON LIVE DATABASE

	JP2K	JPEG	WN	GB	FF	ALL
SROCC	0.9558	0.9724	0.9574	0.9473	0.9514	0.9523
PLCC	0.9524	0.9709	0.9645	0.9492	0.9433	0.9506
RMSE	8.4314	7.5546	5.7865	5.8132	8.9312	8.4433

TABLE II. PERFORMANCE COMPARISON FOR SEVEN IQA METRICS ON THREE TEST DATABASES

		PSNR	SSIM	IFC	VIF	VSNR	SPARQ	OMLQ
SROCC	LIVE	0.8756	0.9479	0.9259	**0.9636**	0.9274	0.9310	0.9523
	CSIQ	0.8057	0.8756	0.7671	0.9195	0.8106	0.9460	**0.9465**
	TID	0.5531	0.7749	0.5675	0.7491	0.7046	0.7920	**0.8356**
PLCC	LIVE	0.8723	0.9449	0.9268	**0.9604**	0.9231	0.9280	0.9506
	CSIQ	0.8000	0.8613	0.8384	0.9277	0.8002	0.9390	**0.9433**
	TID	0.5734	0.7732	0.7340	0.8084	0.6820	0.8200	**0.8228**
RMSE	LIVE	13.3600	8.9455	10.2641	**7.6137**	10.5060	10.1850	8.4433
	CSIQ	0.1575	0.1344	0.1431	0.0980	0.1575	0.0900	**0.0871**
	TID	1.0994	0.8511	0.9113	0.7899	0.9815	0.7680	**0.5975**

 ISBN: 978-1-61208-641-5

III. EXPERIMENTAL RESULTS

Three publicly benchmark databases including LIVE [14], CSIQ [15] and TID2008 [16] are involved. Each database consists of hundreds of degraded images with Mean Opinion Score (MOS) or Differential Mean Opinion Score (DMOS). It is customary to nonlinearly map the metric scores to the ones that have a linear relationship with the subjective scores. Three commonly used performance metrics, including Spearman Rank Order Correlation Coefficient (SROCC), Pearson Linear Correlation Coefficient (PLCC), and Root Mean Squared Error (RMSE) are adopted to evaluate the IQA model. As mentioned previously, there are three parameters, i.e., the scale factors λ_1 and λ_2 for the detection of visually important regions, and stability parameter C for feature similarity, which are determined by training. The training set consists of all images from LIVE database. For each λ_1 and λ_2, which are changed from 0.3 to 0.8 in step of 0.1, and for C, which is changed from 0.01 to 0.1 in step of 0.01, the best values are found by maximizing the SROCC value of OMLQ metric on the training set. When λ_1=0.7 , λ_2=0.6 , and $C = 0.05$ are used, SROCC reaches the peak by performance tuning. To validate the performance of OMLQ on different distortion types, the individual experimental results on LIVE database are summarized in Table I. For each distortion type, we can see this metric has good performance whether it is an individual distortion or a crossover distortion test.

We have evaluated the performance of the proposed metric with other six IQA metrics: PSNR, SSIM [3], IFC [8], VIF [7], VSNR [6] and SPARQ [2]. Table II lists the performance indicators on the three databases, where the best value across the seven IQA results is highlighted in boldface. It is clear that our metric outperforms other IQA metrics in CSIQ and TID2008 databases. Although the result in LIVE database is inferior to VIF, its SROCC value and PLCC value have already been reached 0.95, which means the proposed metric can accurately predict the perceptual image quality.

IV. CONCLUSION

In this paper, we proposed a novel metric for color IQA. It is based on the assumption that an image's VS map has a close relationship with its perceptual quality and online learning can exploit the low-dimensional manifold embedded in high-dimensional data. Our contribution in this work is that we apply manifold learning to IQA. The proposed OMLQ was thoroughly tested and compared with six state-of-the-art IQA indices on three publicly benchmark databases. The results demonstrated that OMLQ could yield much better results in terms of prediction accuracy than all competing methods.

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 ISBN: 978-1-61208-641-5

A Survey of Power-Aware Network-on-Chip Design Techniques

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***Abstract*—The Network-on-Chip paradigm has been heralded as the solution to the communication limitation that System-on-Chip poses. As we usher into the billion-transistor era, Network-on-Chip which was once deemed as the solution is defecting due to its power demanding components. Several techniques have been proposed over the years to improve the performance of the Network-on-Chip, trading off power efficiency. However, low power design solution is one of the essential requirements of future Network-on-Chip based System-on-Chip applications. Power dissipation can be reduced by efficient routers, architecture saving techniques and communication links. This paper presents recent contributions and efficient saving techniques at the router, Network-on-Chip architecture and Communication link level.**

Keywords: Network-On-Chip; Power Consumption; Many-Core; Routers.

I. Introduction

Transistor size reduction in Complementary Metal-Oxide Semiconductor (CMOS) technology has resulted in the duplication of many-cores integration on the same die [1] [2]. As a result of this complexity, the conventional bus interconnect becomes inadequate for future System-on-Chip (SoC) designs as they are constrained from delivering an assured Quality of Service (QoS) and bound to scalability issues and bandwidth limitation [3]. To mitigate this problem, Network-on-Chip (NoC) is proposed to enable simultaneous communication in a high integrated Multi-Processing-Element (MPE) system [4]–[6]. At the same time, this multiplies the power consumption and contributes to the excessive thermal issues (reliability, lifetime of systems, hotspots, chip damage) currently limiting the number of Processing Elements (PE) that can powered-on in MPE systems [7] [8]. NoC contributes to 40% of the chip's total power and increases as the network is extended. As a result, the number of powered-on PE in an MPE system will be limited leading to a degrade in performance.

To overcome this challenge, extensive research has been done in reducing the power consumption of NoC's resources with more emphasis on leakage power due to its consumption of the majority of the on-chip power [9]–[13]. Depending on the workload, the leakage power of a network can vary between 30-90% of the total power and therefore, optimal solutions are required for the development of deeper scaling in technology [14] [15]. Nevertheless, the switching activities of NoC's components have also received some attention [16] [17]. To reduce dynamic power consumption, Dynamic Voltage Frequency Scaling (DVFS) schemes are generally employed.

DVFS vary the voltage frequencies of working components based on the network load. Such techniques predict the network load and supply the amount of voltage required for a successful operation without impacting the performance [18]. Phan et al. [18] proposed an DVFS algorithm which incorporates a controller to monitor the activity of a router through its ports. Based on the traffic load of the ports, the controller supplies the required amount of voltage and frequency. However, varying the frequency of some tasks may result in errors and missed deadlines. Subsequently, a widely popular technique employed to reduce the leakage power consumption in technology is Power-Gating (PG). PG is normally used to power-off NoC components when the network is under-utilized. However, PG can affect the performance of the network and therefore, power efficiency becomes an important factor in many-core design architectures.

This paper presents a study of recent contributions on low power techniques for NoC design. Particularly, to achieve this, we investigated the power saving technique into three main levels. The rest of the paper is organised as follows. Section II explains about the NoC router architecture. Section III discusses efficient techniques for power in NoC architectures. Section IV provides techniques for communication links and finally, Section V concludes the paper.

II. Router Architecture

Routers occupy majority of the NoC's power consumption and therefore are widely selected as the best candidate for mitigating leakage power consumption. A typical router architecture consists of a buffer, crossbar, input and output ports. Moreover, existing literature [16] reveals that 33% of dynamic power in routers are consumed by buffers. Notably, the input buffers are shown to consume 44% of router power and occupy 15% of area [19]. Since buffers occupy majority of the power and occupy large area, many architectural designs have been proposed to overcome this challenge. One such proposal is the bufferless router concept. Bufferless routers employ

 ISBN: 978-1-61208-641-5

algorithms to route packets without temporally storing it [20]–[22]. However, this develops a bottleneck when the network packet injection rates rise eventually leading to livelock and deadlock. Deadlock in bufferless routers occur when two packets arise at the same time and contest for the same port. To solve this problem, existing work propose algorithms which grants access to one packet while the other is redirected on another route leading to livelock thus increasing the power consumption. Therefore, it is not practical to design a network which completely dismisses buffers.

Subsequently, the crossbar switch also consumes a significant amount of power. Increase of PE in MPE systems increases crossbar sizes and therefore adds complexity, scalability issues and large area as well as power consumption as shown by the amount of the power Intel's teraflops processor and MIT RAW crossbars consume [23]–[25]. Therefore, to reduce the power consumption of the routers, existing work have utilized novel techniques to improve power efficiency, the crossbar size, arbiter, and buffer designs. For this purpose, this paper focuses on optimized power saving techniques at the buffer and crossbar level.

A. Router Architecture Techniques

The employment of buffered routers trade-off area and power consumption to prevent deadlock, livelock, and high throughput. Alternatively, Virtual Channels (VC) are employed in buffers to enable parallelism. VC allows multiple access to a physical channel simultaneously. However, they consume a significant portion of NoC routers. Unfortunately, completely dismissing buffers leads to a poor performance network. To defuse this situation, many architectural designs have been proposed. This section of paper presents techniques which can improve the power performance of buffers.

1) Reduction in the pipeline stages: The many stages (Buffer Write (BW), Route Computation (RC), Virtual Channel Allocation (VA), Switch Allocation (SA), and Switch Stage (ST)) that a packet must traverse through to reach its destination increases latency and power consumption. For this purpose, Noghondar et al. [26] proposed an arbitration method which reduces latency and power consumption as well as contention among flits. The proposed arbitration method assigns priority levels to each input port and the port with the highest priority is granted access to its required output port. To prevent latency of low priority ports, a counter is employed to keep track of the cycles that a flit has been delayed for. When the delay exceeds the threshold of the flit, the low priority port is granted access to the output port.

Likewise, Postman et al. highlights in [27] and propose the SWIFT NoC. The SWIFT NoC reduces power consumption by allowing flits to bypass the buffering stage in one (1) cycle; averting the use of read and write power.

Shenbagavalli et al. [28] on the other hand approach this issue by proposing a hybrid scheme which combines circuit and packet switching to allow flits to traverse through the network with only one (1) stage. Compared to virtual point to point connections, this hybrid scheme achieves a reduction of 6.8% in latency and 11.3% in power.

2) Power-gating Techniques: As previously stated before, PG disconnects idle resources from their voltage source to save more power for actual computation. The following authors employed PG to power-off VCs. Muhammad et al. [29] employed PG to activate and deactivate VCs based on the network's workload. In this architecture, VCs are divided into separate groups. Based on the workload, the groups are activated and deactivated. Similarly, Zhan et al. [17] employed PG to activate and deactivate grouped VCs. However, the power savings of the Zhan's architecture, is higher than Muhammad's because of the employment of Spin-Transfer Torque Magnetic Random-Access Memory (STT-RAM) which consumes less power than the conventional Static Random-Access Memory (SRAM). In addition to this, Zhan's VCs can either be powered-off or set into a drowsy state which decreases the wake-up time. Consequently, Nasirian et al. [30] employs PG to disable idle buffers by tracking its inactivity cycle state.

Unfortunately, to achieve a high-power savings, routers must be shut down for long periods of time because the continuous shut down of components incur non-negligible power overhead. For this purpose, existing work propose complex algorithms to route packets through different channels. Unfortunately, such algorithms require knowledge of the network to prevent deadlock and livelock [31]. Consequently, this adds extra complexity and functionality and increases the power consumption as well as possible latency issues. Additionally, the wake-up time for powered-off routers to be activated in time for incoming traffic introduces delay and causes performance degradation. Chen et al. [32] proposed a solution to transmit wake-up signal 3 hops ahead, ensuring intersecting routers which are powered-off are activated in time.

3) Substitutes to Input Buffers: Input buffers particularly consumes a staggering amount of power. To maintain performance whilst also mitigating the power consumption, many designs propose alternatives to input buffers. Kodi et al. [33] proposed an architecture which employs dual-function links and utilizes dynamic router allocation to assign flits to any free buffer. DiTomaso et al. [16] proposed QORE, an architecture which improves power consumption using power-efficient Multi-Function Channel buffers (MFC) and enhances the performance through reversible links. The use of MFC enables the channel buffers to be utilized instead of the routers in the buffers. Li et al. [34] deals with power consumption by replacing the conventional SRAM with Embedded Dynamic Random-Access Memory (eDRAM). Significantly, the buffer area was reduced by 52% and power by 43%.

B. Crossbar Switches

A crossbar switch is composed of individual switches arranged in a matrix form between several inputs and outputs. Crossbar size increases as the network gets larger. This amplifies the power consumption. Crossbar switches can be categorized into two groups, single stage and multi stage.

 ISBN: 978-1-61208-641-5

1) Crossbar size: To achieve low power consumption and small area, existing work focuses on splitting large crossbars into smaller crossbars. Kim et al. [35] proposed a router architecture composed of two crossbars. In the proposed router architecture, the employment of smaller crossbars reduced the size of the Virtual Channel Arbiter (VCA), Switch Arbiter units (SA) and shorter logic depth. Similarly, an optimized crossbar is proposed by the Park et al. in [36] which combines decomposition and segmentation to effectively reduce power consumption by 35%. The crossbar has been disassembled in two small crossbars to reduce area and power. However, in a large-scale network, there will an increase to latency and contention issues.

Emerging crossbars are being built based on multi stage crossbars such as the Clos and Benes network [37] [38] [39] because of their provision of low power and smaller area. Yikun et al. [40] conducted a study on Circuit design and concluded that the Clos network outperform their counterparts (Benes and Single stage Crossbars) in several ways. In the Clos network, there is a reduction in the number of logic unit used. The Benes network suffers from 65% delay in timing and less power in Clos consumed because of the size of crossbars.

Naik et al. [41] proposed a heterogeneous NoC embedded with circuit switched routers composed of buffered and bufferless routers and a 3-stage Clos network. In comparison to a crossbar switch of the same size, the results of this is a reduction of 26% in power consumption and 32% in area. However, circuit switched network causes additional latency when a transmission is established between a source and its destination.

2) Switching Algorithm: In theory, there are two different types of routers; circuit switching routers and packet switching routers. In packet switching routers, data is encoded into packets and routed individually through the network. Circuit switching routers on the hand establishes a connection between the source and destination and specifically allocate resources which will be used for transmission [42]. In Circuit switching routers, there is guaranteed throughput because all packets can be transmitted at the same time without delay in any router. However, there is an increase in latency. This is because during the transmission process, the resources allocated cannot be accessed.

For this purpose, CirKET switching mechanism has been proposed by the authors in [43] to effectively use the benefits of packet switching and circuit switching. In this architecture, messages are split into different groups; High priority and Low priority. High priority messages are transmitted using circuit switching and low priority messages are transmitted using packet switching. The employment of these two mechanisms allow power rails to be disconnected and power-gating to be used to disconnect parts of the router which are not used during a transmission.

III. Low Network Architecture

Novel NoC architectures have been proposed to reduce the average packet latency while increasing the throughput. However, this is usually at the expense of power consumption. To combat the challenges imposed by these power Hungry NoCs, various architectures have been proposed.

The exponential increase in the number of cores in multi-core over the last decade has resulted in the emergence of Three-Dimension (3D) NoC as the platform for On-Chip communication [44] [45]. 3D NoC allows multiple silicon layers to be stacked together to not only enhance the throughput and latency, but also to reduce power consumption [46] [47]. In 3D NoC, the lengthy wires are replaced with short wires through silicon vias (TSVs) to minimize the number of hops it takes for a packet to traverse through the network. Particularly, the increase in the number of links in 3D Integrated Circuits (IC) allows the transmission of more messages around the network [48].

Debora Matos et al. [49] proposed the 3D HiCIT, an architecture comprised of two hierarchical levels with a mesh topology at the top level. In comparison with the traditional 3D spin and 3D mesh topologies, the proposed architecture reduces the average latency to 50% and 54% respectively, with the 3D spin been the latter [49]. In addition to this, the architecture is comprised of a crossbar and low-cost routers. Compared to the 3D spin and 3D butterfly fat tree topologies, the proposed architecture uses less TSVs.

Stacking of multiple silicon layers in 3D IC reduces hop-count in comparison with the long interconnect wires in Two Dimension (2D) NoC. However, limitations such as power density caused by the chip size, the cost of TSV and its defects [50] [49] prevents 3D NoC from reaching its potential. For this purpose, the author in [51] recommends the use of monolithic 3D. One approach to reduce power consumption is to use fewer buffers at the router port [52]–[54]. Similarly, Fang et al. [55] proposed Reduce Router Counts and Increase Efficiency Service (RRCIES), an architecture based on a mesh topology. RRCIES allows multiple cores to be connected between one router. As a result, hop distance is reduced. The use of fewer routers constitutes to a reduction in power hungry components such as buffers, crossbar, switches, and virtual channels.

Another alternative is to employ PG. The study of vertical slit field effect transistors led to the proposal of a 3D Hybrid architecture in [56]. PG and clock gating are employed in this architecture to enable different level of buffers to be deactivated. The proposed architecture splits the input buffers into three (3) levels. Each input port is designed to access all three levels and permit any virtual channel destination to be chosen. In addition, the buffers from ports which are not being used are shared among busy ports.

IV. Communication Links

Although routers consume more power in NoC, the communication links can be optimized to accommodate this. According to [57] and [58], routers and communication channels contributes to most of the power consumption in NoC. Therefore, existing work have developed techniques to reduce the amount of power consumed by the links.

 ISBN: 978-1-61208-641-5

1) Voltage Scaling : The voltage swing in the communication links can be optimized to reduce the amount of power it consumes. However, this is at a cost of a rise in error bit rate. For this purpose, Mineo et al. [59] proposed to reduce power consumption by using a technique which permits two working levels in a link. A flag is attached to each communication to identify their priority. Low prioritised communications (Body and Tail flit) can be transmitted on a low-level voltage swing while the others (Head flit) can be sent using a normal level voltage.

2) Half-cycle Flits : The longer flits traverse through the links in NoC, the more power is consumed. Therefore, decreasing the number of cycles of it takes from a flit to transmit between routers would not only enhance the performance of the network but also save power. A. Psarras et al. [60] proposed a technique which allows flits to only use half a cycle to hop between routers. By allowing flits to spend less time in the links, less power is consumed compared to single cycle routers where one cycle is used to execute all operations in the router and one is used to hop between routers.

V. Summary of contribution

Table I presents a summary of the techniques. The table presents three categories (Techniques, Performance degradation and power saving). The Technique categories presents all the techniques which have been presented in the paper. The performance degradation category shows the impact that the applied technique has on the performance on the architecture. Lastly, the power saving technique shows the amount of power savings that the applied technique saves when applied to the architecture.

From the table, it can be concluded that there is a balance between performance and power when alternative buffers are used. Additionally, employing PG also impacts on the performance and power of the architecture.

VI. Conclusion

In this paper, several NoC power saving techniques have been critically evaluated. Particularly, the effect of buffered and bufferless routers on power consumption have been presented. Moreover, a summary of these techniques has been presented to compare their trade off. The combination of some of the architectures presented, if employed, can help improve the amount of power consumed by NoC resources which can either be removed or switched off. Whether it being the adjustment (crossbar size, buffers, virtual channels) of the components in the router architecture, modifying the architectures (resource management) and the amount of voltage used in the communication links. Also, we explored low power techniques used in emerging NoC Architectures; 3D NoC and WNOC. Based on our discussions, we can conclude power dissipation can be reduced in all areas of a network infrastructure. Our future work will be focused on accessing the power consumption of the memory subsystem. Particularly, on the Last Level Cache [61] [62].

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 ISBN: 978-1-61208-641-5

TABLE I
LLC SRAM AND STT-RAM TECHNOLOGY COMPARISONS

Techniques	Performance Degradation	Power Saving
Power Gating	Medium	Medium
Alternative Buffers	Medium	High
Pipeline Stages	Low	Low
Voltage Scaling	Low	Low
Half-cycle Flits	Low	Low

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