Why are 3D Apparel CADs Not Used?

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Abstract

A 3D CAD is one of latest innovations in apparel industry. Despite a rapid progress of related technologies and an emergence of several commercial products in markets, an adoption of 3D CAD tools in apparel industry is much slower than originally expected. In an effort to diffuse such a technological advance in apparel industry, more behavioral studies of why and how apparel designers adopt and use a 3D CAD are needed. Toward that goal, this study aims to identify more about whether such an adoption decision would be more associated with organizations or individuals. Using TAM and TOE framework, the study findings show that the intention to adopt 3D garment CAD is more explained by individual attitudes rather than organizational characteristics.

Keywords : Fashion CAD, 3D Apparel CAD, Technology Adoption

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1. Introduction

Three-dimensional modeling is an outcome of big advances in computer graphics. Such a technology soon began to be utilized in computer-aided design (CAD) as well. 3D CAD is a tool which allows users to create three-dimensional computer-generated imagery and then, based on that, change, stretch, and view that as they wish.

Among many CAD domains, apparel design field has also caught potential benefits from 3D technology. Okabe et al. [1992] introduced using a three dimensional apparel CAD system. Thereafter, many more studies have been done about 3D apparel CAD system. Most of them, however, have focused on engineering aspects of such system [Kang et al., 2000a, 2000b; Liu et al., 2010].

There have been some studies to deal with non-technical issues such as managerial and social aspects of apparel CAD. In an effort to facilitate CAD usage, McLoughlin [1991] and Bertolotti et al. [2004] have emphasized that more human-centered approach and more managerial interventions are needed. Though important issues with respect to CAD usage were proposed, their claim was not empirically tested. An empirical study was made by Yan and Fiorito [2007] to investigate why apparel firms adopt and diffuse an apparel CAD. In their study of examining determinants which would affect the diffusion of apparel CAD in apparel industry, they have found that an adoption of apparel CAD was driven primarily by the market pressure [Yan and Fiorito, 2007]. However, 3D CAD was not the target of their study.

3D CAD is an entirely different matter from 2D CAD. Despite the large potential of changing the way an apparel firm does business in future, 3D apparel CAD is being adopted at a lagging pace [Mastnak, 2000]. In an effort to study how British apparel firms adopt and use apparel CAD technologies, Easters [2012] identified that, whilst 2D CAD tools are currently used effectively in most apparel firms, 3D CAD technology is not seen yet as being effective enough. In this regard we believe it is important to understand why apparel designers adopts or not adopts 3D CAD.

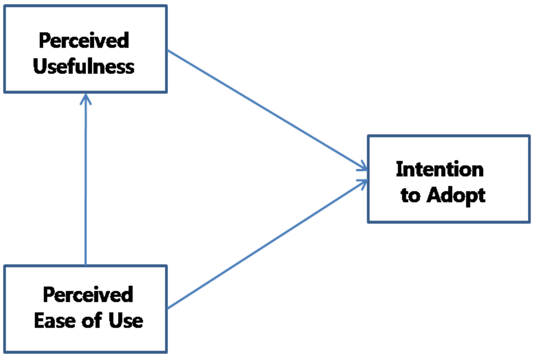
Motivated by such concerns, we aim to determine whether the adoption of 3D apparel CAD hinges more on organizational factors or individual designers' attitude. To be more specific, by comparing the power of explanation on the intention to adopt a 3D CAD tool through TOE framework or TAM respectively, we hope to deepen our understanding about the adoption of 3D CAD.

2. Backgrounds and Research Models

2.1 Models for Explaining Technology Adoption

Why people adopt and use a technology is a major research question in the IS community. As expected, the IS community attempted to propose a number of models to explain an adoption and use of a technology. These models can be classified into two : individual adoption and organizational adoption.

Among a number of individual adoption models, the most-known one is Technology Acceptance Model (TAM). TAM proposed by Davis [1989] is taking a quite parsimonious approach. That is, adoption intention can be explained by two belief constructs, perceived usefulness (PUS) and perceived ease of use (PEU), and furthermore PEU would have a positive association with PUS, as shown in <Figure 1>.

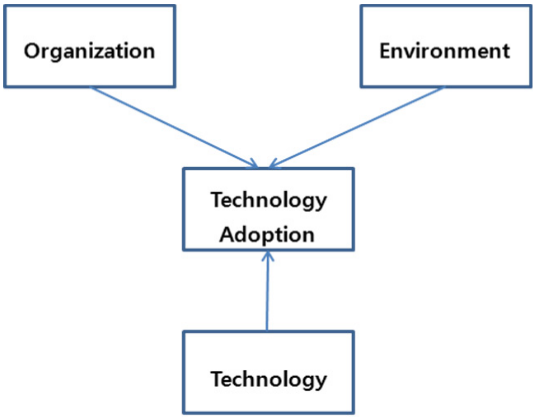


〈Figure 1〉 Technology Acceptance Model

Because of the simplicity and the strongly theoretical foundation of the model, TAM has been applied to a wide selection of technologies and users. Subsequently, extensions or revisions to TAM were made in its following studies. TAM2 [Venkatesh and Davis, 2000] and Unified Theory of Acceptance and Use of Technology (UTAUT) [Venkatesh et al., 2003] are good examples. In an effort to compare these models, King and He [2006] has ever found, through a meta-analysis using 88 published TAM studies, that the original TAM is "a powerful and robust predictive model".

From an organizational perspective, there are two models that have gained much attention from researchers. One is Rogers' [1962] Diffusion of Innovation (DOI) theory. Using core constructs mainly from sociology, it was designed to explain how innovation spreads through an organization or a society. It was Moore and Benbasat [1991] that adapted its original constructs so that they could be used under individual technology adoption situations.

The second one is Technology-Organization-Environment (TOE) framework developed by Tornatzky and Fleischer [1990]. This framework has identified three aspects which would influence organization's technological innovations : technology, organization, and external environment. <Figure 2> shows the general model of TOE framework.



〈Figure 2〉 TOE Framework

2.2 The Use of 3D Apparel CAD Technology

3D technology is one of latest technical breakthroughs. Each industrial player may adopt and use it in order to upgrade its internal process or to enhance its competitive advantage in the market. Industries following this track include gaming, entertainment, film, product designing, and manufacturing. They use 3D imagery technology as a tool for representation or manipulation, facilitating more automation in their work practices.

Recently apparel industry has also joined such voyage. However, the apparel sector which inherently requires more manual intervention by specialized humans could not achieve as much automation from 3D CAD technology as originally expected [Kang et al., 2000a]. Most of subsequent studies, therefore, have focused on devising technical solutions or improvements [Kang et al., 2000a, 2000b; Lie et al., 2010; Fontana, et al., 2005]. Driven by relentless studies in computer graphics and computer-aided design, major improvements were made with respect to 3D human body measurement and modeling, 3D apparel design on digital human models, 3D draping simulation, and 2D pattern generation from 3D space [Liu et al., 2010]. Such improvements have contributed to an emergence of a number of commercial products. Nowadays, more than a dozen are available in the market.

There are only a few studies regarding apparel CAD usage. Yan and Fiorito [2007] studied about how CAD/CAM is diffused in the apparel industry. They have found that the higher the external pressure they experience, the more diffused CAD/CAM will be within the firm. However, their study did not include 3D apparel CAD. The sharp distinction between 2D CAD use and 3D CAD use was identified by Easters [2012]. Through a set of interviews with apparel designers and managers, he has found that, whilst 2D CAD tools are currently used effectively in most apparel firms, 3D CADs are not. There is an indication that, unlike 2D CAD, the industry seems to resist the full adoption of 3D technology. Some of the interviewee suggested that 3D CAD would be not a great help to apparel designing tasks and instead may be best suited to marketing and promotion tasks. However, this unexpected result was not empirically validated.

3. Research Model and Hypotheses

An adoption or intention to adopt an innovative solution within an organization is not a simple decision-making. It is kind of a composite decision in which not only organizational aspects but also individual attitudes need to be reflected. With respect to organizational decisions, it may have to take into consideration whether such technology fits organizational contexts or environmental circumstances of the organization. At the same time how the technology is perceived by individual users in terms of usefulness or ease of use also does a part.

In this study we use TOE framework for organizational decision about 3D apparel adoption. With TOE studies, a wide range of determinants have been suggested in the literature [Wang et al., 2010; Chau and Tam, 1997; Teo et al., 2006]. In this study we selected a few determinants which are believed to be relevant to 3D apparel CAD adoption. Relative advantage, complexity, and compatibility were chosen for technological context. Top management support and firm size are the chosen factors for organizational context. And, competitive pressure was selected as one determinant for environmental context.

With respect to the dependent variable, we took into consideration the current situation that 3D apparel CAD are not heavily adopted and used in the Korea apparel industry. So, instead of the adoption itself, we chose the intention to adopt 3D apparel CAD.

We therefore propose 7 hypotheses as below :

H1 : Relative advantage is positively related to the intention to adopt 3D apparel CAD.

H2 : Complexity is negatively related to the intention to adopt 3D apparel CAD.

H3 : Compatibility is positively related to the intention to adopt 3D apparel CAD.

H4 : Top management support is positively related to the intention to adopt 3D apparel CAD.

H5 : Firm size is positively related to the intention to adopt 3D apparel CAD.

H6 : Competitive pressure is positively related to the intention to adopt 3D apparel CAD.

Regarding individual decision about 3D apparel CAD, we just used two major determinants about individual intention to adopt : perceived usefulness and perceived ease of use [Davis, 1989]. Since the major goal of our study is about the relationship between TAM's two well-known determinants and the dependent variable, the intention to adopt, the relationship between perceived ease of use and perceived usefulness was disregarded.

So, two other hypotheses were proposed as following :

H7 : Perceived usefulness is positively related to the intention to adopt 3D apparel CAD.

H8 : Perceived ease of use is positively related to the intention to adopt 3D apparel CAD.

4. Research Design

We below describe in brief about the instrumentation, sampling method, and scale validation process.

4.1 Instrumentation

Our instrument was constructed by taking and adapting scales from previous studies. Relative advantage (ADV), complexity (CPX), firm size (SIZ), and compatibility (CPT) constructs were adapted from Grover [1993]. Management support (MAN) construct was adapted from Soliman and Janz [2004] while competitive pressure (PRE) construct from Iacovou et al. [1995].

And, TAM's independent constructs such as perceived usefulness (PUS) and perceived ease of use (PEU) were adapted from Davis' original work about TAM [1989]. Intention to use (INT) construct was adapted from Davis [1989] with a little modification. Each item was measured using a 7-point Likert scale. <Table 1> shows the measurement items.

<Table 1> Constructs and Measurement Items

Constructs	Theory Basis	Item description
ADV	TOE	**ADV1** 3D apparel CAD will help us to respond rapidly to market. **ADV2** 3D apparel CAD will help us to eliminate wastes during design stage. **ADV3** 3D apparel CAD will help us to bring an innovation in the design stage.
CPX	TOE	**CPX1** Our firm thinks that it is complicated to use 3D apparel CAD. **CPX2** Our firm thinks that complicated procedures are required to implement and use 3D apparel CAD.
CPT	TOE	**CPT1** 3D apparel CAD can be used associated with existing technology infrastructure (eg., 2D apparel CAD). **CPT2** 3D apparel CAD can be introduced without major changes in related processes and work practices.
MAN	TOE	**MAN1** Our management is likely to invest in3D apparel CAD. **MAN2** Our management is likely to cope with risks occurring at the introduction of 3D apparel CAD. **MAN3** Our management is likely to get interest in 3D apparel CAD in order to increase our competitive advantage. **MAN1** Our management is likely to think that an introduction of 3D apparel CAD is a strategically important thing to do.
SIZ	TOE	**SIZ1** The capital of my firm is high compared to the industry. **SIZ2** The revenue of my firm is high compared to the industry.
PRE	TOE	**PRE1** My company has ever faced competitive pressure to introduce 3D apparel CAD. **PRE2** My company would have faced competitive disadvantage if 3D apparel CAD had not been adopted.
PUS	TAM	**PUS1** 3D apparel CAD will enhance my job quality. **PUS2** 3D apparel CAD will enhance my job efficiency. **PUS3** 3D apparel CAD will enhance my job satisfaction.
PEU	TAM	**PEU1** It is not difficult to use 3D apparel CAD. **PEU2** It is feasible to understand functionalities of 3D apparel CAD. **PEU3** It is accustomed to using apparel CAD-related technologies.
INT	TAM/TOE	**INT1** It would be meaningful to use 3D apparel CAD in my work. **INT2** It would be desirable to use 3D apparel CAD in my work. **INT3** It would be much better for me to use 3D apparel CAD. **INT4** Overall, I like using 3D apparel CAD.

4.2 Data Collection

To collect data for our study, a questionnaire survey was administered in Korea. A mailing list of apparel design professionals compiled by a private apparel CAD training institute was used. The list consists of apparel designers or managers who the institute usually contacts with in order to make an announcement about CAD training program or to help program graduates find a job. E-mail questionnaire was sent to the 148 professionals with a suggestion that email forwarding can be made to some other colleagues in the firm or in the industry as long as they are engaged in apparel design work. We received 80 useful responses. Among them, there were 5 respondents who are working at an organization in which 3D apparel CAD was already adopted. We decided to remove them from our analysis because a study of technology adoption intention presupposes that sub-

〈Table 2〉 Summary of Demographic Information of Respondents

Job title	Percentage	Experience	Percentage
Fashion designer	31%	Less than 3 years	15%
Pattern Maker	31	3~5 years	12
Grader/Marker	11	5~10 years	41
Merchandiser	15	10~20 years	19
Others	13	More than 20 years	13

jects have not yet decided to use such a technology.

As shown in <Table 2>, most of the survey respondents hold a job title directly related to apparel design. They seem to have an enough experience to answer about our questions. And, 63% of the respondents had an experience of using 2D apparel CAD before.

5. Data Analysis and Results

5.1 Reliability and Validity

For validity analysis, factor analysis with principal components analysis and varimax rotation was used. Though six factors were originally expected, the results indicated that some of construct modification is necessary as shown in <Table 3>. Competitive pressure and management support were combined into a single factor, implying that the firm's stance to 3D apparel CAD in competitive environments and management's attitude with respect to 3D apparel CAD were viewed similarly. So we just renamed the combined construct as "competitiveness."

And, compatibility and relative advantage were also combined into one factor. We think that apparel designers are having a bigger picture in which both benefits from and prior requirements to 3D apparel CAD are viewed in a holistic sense. The newly integrated construct we call as "feasibility." Two other constructs were classified as expected. TAM's two constructs were classified successfully as shown in <Table 4>. All of their Cronbach's alpha values also met the criteria $\alpha \geq 0.70$, as shown in <Table 2> and <Table 3>.

〈Table 3〉 Validity of TOE Constructs

	factor				Chronbach's alpha
	1	2	3	4	
PRE1	.834	-.014	.022	.002	0.917
PRE2	.777	.112	.074	-.331	
MAN4	.698	.338	.452	-.091	
MAN3	.669	.357	.505	.005	
MAN2	.608	.480	.509	-.030	
MAN1	.601	.466	.514	.022	
CPT2	.125	.785	.113	.264	0.877
CPT1	-.098	.782	.287	-.195	
ADV2	.419	.690	.143	-.328	
ADV3	.393	.674	.209	-.407	
ADV1	.450	.652	.195	-.416	
SIZ1	.157	.113	.906	-.096	0.879
SIZ2	.136	.252	.865	-.102	
CPXC2	-.044	-.081	.011	.913	0.841
CPXC1	-.122	-.087	-.153	.871	

〈Table 4〉 Validity of TAM Constructs

	Factor		Chronbach's alpha
	1	2	
POU2	.925	.301	0.927
POU1	.891	.290	
POU3	.798	.416	
EOU2	.278	.851	0.856
EOU1	.302	.825	
EOU3	.344	.809	

5.2 Regression Analysis

First, the regression analysis based on TOE framework shows a mixed result. As displayed in <Table 5>, complexity and feasibility were found respectively to be a significant predictor of 3D apparel CAD adoption. It indicates that the more feasible and the easier to use, the more likely apparel designers adopt 3D apparel CAD. However, competitiveness has no relationship with the intention to adopt 3D apparel CAD, implying that apparel designers do not yet view 3D apparel CAD as a strategic weapon. It appears that it is contrary to Yan and Fiorito [2007]'s finding. And, the result that there is no association between firm size and the intention may tell us that the amount of investment required in introducing 3D apparel CAD is not a big obstacle to adopting it.

Second, the regression analysis based on TAM, as shown in <Table 6>, confirms most of findings in previous TAM studies that perceived usefulness is a good predictor about technology adoption intention but perceived ease of use is not.

Finally, we compared the explanation power of both models in an effort to determine which models could more explain the intention to adopt 3D apparel CAD by apparel designers. R2 was used for this purpose. R2 in TOE analysis was 0.283 while R2 in TAM was 0.438. It indicates that TAM explains today's attitude of apparel designers about 3D apparel CAD much more than TOE does.

6. Discussion and Conclusion

This study has attempted to identify factors that affect the intention to adopt 3D apparel CAD. TOE framework and TAM were applied for organizational and individual perspective, respectively.

The results of our analysis show that feasi-

〈Table 5〉 Regression Analysis of TOE Framework

model		Unstand. Coeff.		Stand. Coeff.	t	Signif.
		B	Stand. Error	Beta		
1	(constant)	5.249	.984		5.333	.000
	competitiveness	.123	.198	.093	.621	.537
	feasibility	.404	.201	.293	2.010	.048
	complexity	-.419	.136	-.335	-3.083	.003
	size	-.431	.138	-.393	-3.133	.003

〈Table 6〉 Regression Analysis of TAM Framework

model		Unstand. Coeff.		Stand. Coeff.	t	Signif.
		B	Stand. Error	Beta		
1	(constant)	-.337	.371		-.907	.367
	PUS	.888	.090	.760	9.852	.000
	PEU	.177	.107	.128	1.656	.102

bility and ease of use (the opposite of complexity) may be a good predictor of 3D apparel CAD adoption. And, perceived usefulness has a strongly positive relationship with the intention, as verified in a majority of existing TAM studies.

Based on the result, we can identify a couple of practical implications. If apparel firms would like to make an innovation with their design process, they need to train their designers so that they can be more experienced with apparel CAD technologies. And, they may have to streamline different, but closely linked activities. For instance, 2D apparel CAD has been mainly used in pattern-making stage. Fashion designers and apparel merchandisers were mainly not within functionalities of 2D apparel CAD. However, with 3D apparel CAD, the whole process of apparel designing activities including apparel planning, designing, pattern-making, and product simulating need all to be applied. It may be the case that, prior to their introducing of 3D apparel CAD, they have to streamline and adjust these interconnected activities so that these activities become more applicable to 3D apparel CAD.

This study has few limitations. First, we used the same dependent construct, the apparel designers' intention to adopt 3D apparel CAD, for organizational as well as individual perspectives. Organizational-level study should have used organization's intention or attitude, instead. One of prime objectives of this study was to compare the explanation power between organization-level adoption models and individual-level adoption models, so we had to use the same dependable construct. Second, an adoption of an innovative solution within an organization should be sort of a composite decision-making choice in which organizational issues and individual attitudes are all combined and affect each other in a reciprocal way. Such more realistic relationship was not reflected in our study.

Future research may have to incorporate these limitations. And, given the fact that apparel designers apparently have a strong intention to adopt 3D apparel CAD, their organizations actually tend not to adopt it. Why is that so? This may probably be an intrinsically more essential question. We may have to borrow ideas from other domains than technology adoption theories.

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